

**2007 Annual Report**  
**for the**  
**CU Science Education Initiative**

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## **I. Overview of Science Education Initiative**

The CU Science Education Initiative is designed to implement and coordinate departmental-wide improvement of undergraduate science education. The major goal of the SEI is to bring about the transformation of the teaching of science on a sustainable department-wide basis to research-based methods that have been shown by CU-Boulder faculty to be highly effective in achieving their defined learning goals.

While it is essential to improve science education at major research universities, the task is formidable. These science departments are large entities with established practices and are subject to a variety of economic and external constraints, providing barriers to change. The approach of the SEI is two-fold: 1) to have the faculty and the department initiate their involvement in and commit to participation in the SEI, and 2) to lower the time and money challenges by providing the funding needed to carry out these department-initiated activities.

The SEI efforts in each department are focusing on sequentially targeting courses for improvement, beginning with the large introductory courses. Working in conjunction with the participating department, the major elements of the SEI-department efforts for each targeted course include: 1) establishing well defined learning goals, 2) determining student thinking, 3) creating valid tools for diagnostic assessment of attainment of learning goals, 4) creating pedagogically effective materials, and 5) developing faculty knowledge and practices.

Below, we provide details on the central SEI activities that are being conducted in support of the project, followed by a summary of the SEI budget. In the last five sections, the participating departments (Chemistry, Geological Sciences, Integrative Physiology, MCDB, and Physics) summarize 1) the structure of the SEI project within their department, 2) the course-related activities in 2007, 3) faculty involvement in the SEI, and 4) departmental goals for 2008.

## **II. Central SEI Activities**

### **A. Changes to Central staff**

The SEI central staff has undergone several changes in the past year. In January 2007, Carl Wieman moved to the University of British Columbia (UBC), in Canada, to start efforts there and establish a UBC-based SEI program. He is now splitting his time between UBC and CU-Boulder, generally traveling to Boulder for several days each month. This move has opened up a lot of opportunities for the SEI, as the departments here at CU-Boulder have had the chance to collaborate with correlating departments at UBC.

In addition, the SEI central staff lost the project coordinator, and now has a new project coordinator, Angie Jardine. This transition was very smooth, as the old project coordinator was able to train Jardine.

### **B. Funding departmental-based efforts**

After the Fall 2005 call for proposals to participate in the SEI was announced, four departments were granted funding: CHEM, GEOL, IPHY, and MCDB. In each of these departments, the funding was enough to hire 2 to three full-time PhD-level Science Teaching Fellows (STFs) to partner with their departmental faculty in carrying out their SEI goals as well as support some additional activities. In 2007, the SEI called for physics to resubmit their proposal. In Spring 2007, the Physics department was granted funding from the SEI. In Physics, the funding is enough to hire 1 full-time PhD-level STF.

Up through the end of 2006, the SEI was still in a state of growth, in terms of staff. Since January 1, 2007, 5 new STFs have been hired (one in each department), completing the number of STFs that the SEI can currently fund (a total of 11 STFs). With the activities in departments growing and more faculty becoming involved, there is an ongoing need for additional flexible funds to support short-term efforts. Departmental SEI faculty liaisons may propose to the SEI central program for additional funding for these projects (e.g. funding for faculty to participate in a 3-day summer working group to develop consensus learning goals).

A summary of the activities in each department is provided in the last five sections of this report.

### **C. Fundraising Efforts**

The SEI central staff (Carl Wieman, Kathy Perkins, Wendy Adams, and Angie Jardine) are working with the CU Foundation (Barb Perin, Director of Corporate and Foundation Relations) to identify potential private or community donors interested in supporting CU's efforts to improve science education. Wieman and Perkins met with several community members involved in education to investigate possible new sources of funding for the project: Dorothy Horrell (Bonfiles-Stanton Foundation), Van Schoales (Piton Foundation), and Tony Lewis (Donnell-Kay Foundation). These efforts will continue as time permits.

Perkins was awarded an NSF grant for \$150,000 to support and expand the SEI-related efforts in Physics, allowing the Physics Department to hire a second STF for 2 years.

### **D. Activities to support departmental-based efforts**

The SEI central staff (Carl Wieman, Kathy Perkins, Wendy Adams, and Angie Jardine) support the departmental-based efforts in a variety of ways:

1. Wieman and Perkins are responsible for training all of the STFs: educating them on the results of learning research, techniques of education research, and new effective teaching practices; reviewing their activities and progress and providing guidance and advice where needed; and providing them with appropriate professional development opportunities.
2. Wieman and Perkins meet monthly with each department's central SEI team (nominally the STFs and the faculty liaison) to review the department's progress on their efforts and their plan for future work. They provide guidance and advice where appropriate. In addition, they provide central support for certain activities where appropriate (e.g. resource materials for workshops or for administering surveys).
3. In order to promote the SEI efforts within each department and to assure faculty that the central SEI team highly values their input into how this effort is structured within each department and how the model for improving education needs to be adapted for their department/course, Wieman and Perkins have been meeting with several new faculty within each department each term.
4. To foster communication between departments, Wieman and Perkins hold weekly meetings with all the STFs, where every other week the STFs from one department report on their activities – sharing with the other STFs the results of their work that they think would be beneficial to the other STFs and soliciting input and guidance from the other STFs on areas where they are having trouble.

5. The faculty liaisons communicate about the activities within each department at the advisory board meetings, held once a month.
6. In May 2007, Wieman, Perkins, and Gratny organized the second end-of-term SEI sharing session – a half day even in which each of the 4 participating departments presented some highlights of their activities over the course of the term with time for discussion among the faculty. Approximately 36 people attended, including about 20 faculty: 4 faculty from the 4 participating departments, 5 faculty from the Physics department (Physics had been approved, but had not yet started their involvement in the SEI), and one faculty member from Applied math.
7. In the past year, the central SEI staff has given several workshops for the STFs, including a workshop to teach them tips for analyzing large amounts of data in Excel, as well as a workshop to teach the STFs tips for calculating different types of statistics using various different programs, including SPSS and Excel. In addition, SEI advisory board member Stan Deetz, who is a Professor of Communications, gave a workshop on how to appropriately handle different types of situations when interacting with faculty.
8. During the Spring 2007 semester, SEI advisory board member Bill Wood and MCDB faculty member Jenny Knight offered a seminar on teaching and learning, which many of the STFs and central SEI staff chose to participate in.
9. The SEI has set up a server for the purpose of sharing files among the SEI staff, the STFs, and among involved faculty within the departments. This server has been used for sharing files such as data from surveys, course materials, literature, etc.
10. The SEI is co-funding work on several new interactive simulations, to be completed in the subject areas of biology and geosciences. This effort is in collaboration with CU's PhET project – an award winning program to create highly effective interactive simulations for learning science. Currently, work is being done on a glacier simulation and a cell membrane simulation. The glacier simulation is a collaborated effort with the CW-SEI at University of British Columbia. The goal is that these simulations will aid the departments in their efforts by providing a resource to be used in courses within the department.
11. Adams provides departmental support and communicates pertinent information related to expenses, hiring, and budgeting.

#### **E. Resources for faculty**

The central SEI staff currently provides and is creating additional central resources for faculty working on improving science education on campus.

##### **1. Workshops/Brownbags**

In Spring 2007, a workshop on defining learning goals and assessing achievement of learning was offered again. This workshop has been offered several other times in 2006.

The IPHY STFs have held multiple brownbag discussions with their faculty throughout 2007. In Spring 2007, IPHY held faculty brownbags addressing the following topics: creating valid and reliable assessment tools, use of clickers, and use of concept maps. In Fall 2007, IPHY decided to hold brownbags for the TAs, addressing the

following topics: misconceptions, metacognition, cognitive load, and tools to help students synthesize course material.

Faculty working groups have been started in several of the participating departments, including Chemistry, Geosciences, MCDB, and Physics. These working groups have been established to tackle various problems in each department. For example, in Chemistry, a working group was started to work on reforming the introductory Chemistry courses, creating a concrete, consistent set of learning goals for these courses.

## 2. Invited Speakers

The central SEI encourages and supports each department in inviting noted education researchers and reforms in their disciplines to participate in their colloquium series. We believe this is the best way to expose additional faculty to this discipline-based education research that is being conducted and is valuable to their efforts as teachers.

Several noted speakers have been: Julie Libarkin (Geoscience Education Research): "A tale of three theories: development of the Geoscience Concept Inventory"; Marcy Towns (Chemistry Education Research) "Using Clickers With 2500 Students: An Analysis of Question Type and Student Response"; and Joe Redish (Physics Education Research) "Problem Solving and the Use of Math in Physics Courses"

## 3. Website

The SEI website provides general information about CU's SEI project and serves as a source for faculty to access information about various education research findings (both general and discipline-specific), handouts and PowerPoint slides from SEI workshop, and course-related resources. These resources are expanding as the SEI work progresses. The website can be found at: <http://www.colorado.edu/sei/>.

In addition, the CU SEI effort is collaborating with the UBC SEI effort to build a much more sophisticated database of resources for faculty that allows faculty to upload their own resources or to search existing resources. This software should be in place by the end of 2008.

## F. Evaluation of the success of SEI efforts

Late in 2006, a proposal was submitted for funding to support the evaluation of the success of the SEI efforts. Although this particular proposal was not accepted, the SEI has been engaged in some evaluation efforts to provide formative feedback to the project.

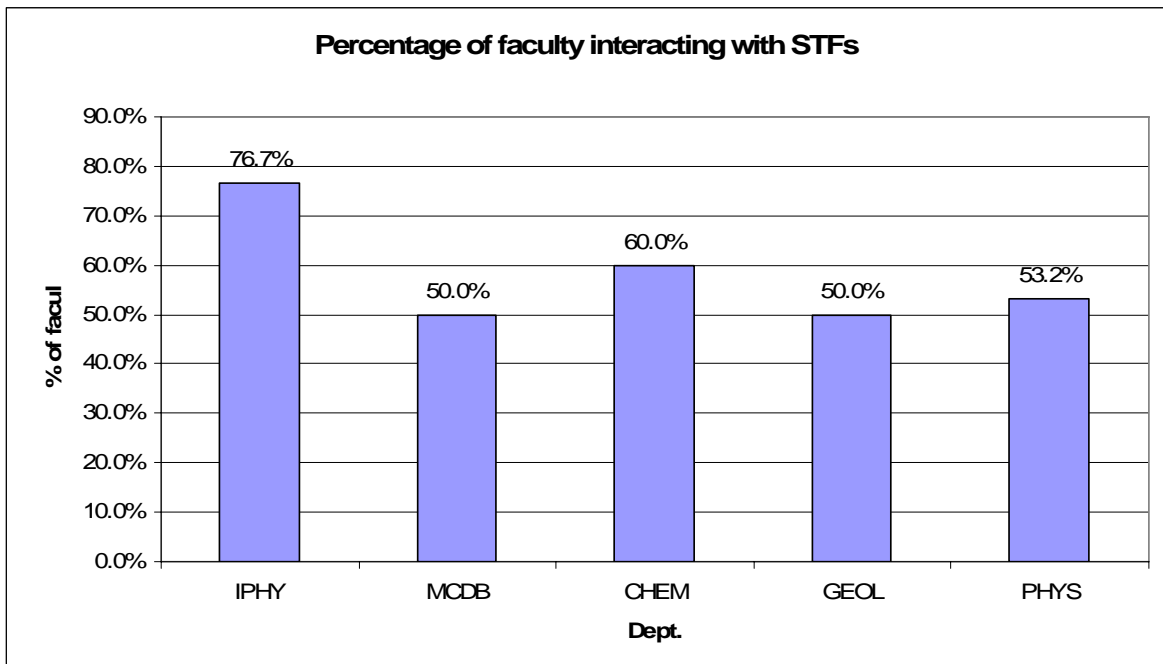
### 1. Observation of courses

The SEI central staff, with the help of several graduate students in physics and education, has conducted observations of several courses in each department. These observations are intended to characterize the way each course is taught. Doing observations of these courses will allow the SEI to characterize the types of teaching being done within each department at the beginning of the project. This will be a baseline to which the departments can be compared at the end of the project.

### 2. Keeping records of STF-Faculty interactions

The STFs have been keeping logs of their interactions with the faculty in their department. These logs help to keep track of how the faculty are using the STFs as well as a general gauge of the faculty's level of SEI involvement.

On average, the STFs interact with about 53% of the faculty in their individual departments. Some of the STFs interact with as much as 77% of the faculty in their department. In Figure 1, you can see a plot of the percentage of department faculty that each STF interacted with during 2007. Of the faculty that the STFs interacted with, on average about 32% of these were regular interactions (taking place more than once every two weeks). The regularity of interactions varies based on the type of work the STFs do. For instance, one STF may be very focused on one course, interacting heavily with only one or two faculty, where another STF may be focused on a variety of things, meaning they interact with a greater number of faculty, but on a less regular basis. The STFs have many different types of interactions with the faculty in their departments, such as group settings, one-on-one meetings, emails, interviews, etc. Some of the STFs' interactions lie heavily in one category or another, where others have a variation of types of interactions. Several of the STFs primarily interacted with faculty in a one-on-one setting (one-on-one meetings accounted for about 80% of two of the STFs' interactions). Several others interacted primarily in a group setting, such as working groups (group meetings accounted for about 80% of one STF's interactions, and about 60% of two other STFs' interactions). Another interesting statistic is that the STFs have quite a few interactions with faculty where the interaction is initiated by the faculty member, that is the faculty members seek them out. On average, 36% of the STFs interactions with faculty were unsolicited by the STF. This number varies depending on the types of interactions the STFs have with faculty, but one STF had as many as 80% of her interactions unsolicited.



**Figure 1: The Percentage of faculty in each department that interacted with STFs during 2007**

### 3. Surveying involved faculty

Through informal conversations and/or surveys of involved faculty, several have shared comments regarding their feelings about involvement with the SEI. Here is some

feedback from a new faculty member in the Geosciences department, who was involved with the SEI from the beginning of her appointment:

*My experience being part of the SEI Geol 1010 teaching group this semester was enormously beneficial on a variety of levels. Teaching my first semester would have been an order of magnitude more difficult without it. I went into this a skeptic, having come from PhD and postdoc programs that heavily emphasized research. I had no past experience teaching, with the exception of acting as a TA for a small undergrad class during my PhD at MIT.*

*I can identify four ways in which I found the SEI experience particularly helpful. First, it saved me a huge amount of time -- something of obvious concern to new faculty. Upon arriving here, I immediately received a dvd containing a library of powerpoints and clicker questions from which to help construct my own lectures. This not only was a time-saver, but also allowed me to see the variety of ways in which different faculty teach the same material. Having a group to talk with once a week about teaching also helped me avoid all kinds of small mistakes -- the class expectations of review sheets prior to exams, how to pass out exams and other materials efficiently in a large class, how to post stuff on CULearn, etc. Second, right away I was engaged in discussions about how to teach, and what is important to teach. Anyone teaching for the first time is going to develop habits, and the bad ones are hard to break. This helped me develop the good habits. Third, our group of four really clicked. I had fun being involved in this. It was a good social outlet, and we now go out for drinks and socialize in non-academic settings. Finally, and most importantly, it provided a crucial reference frame for me to see how I was doing relative to others teaching the same class. It is almost impossible to gauge this on your own. I don't think I can over-emphasize this point. Since our group was giving the same homeworks in each section, and similar exams, I could see that my class was doing as well as the other classes. So, if I had the occasional complaint from students that things were too hard, I had confidence that I wasn't way off the mark and so didn't question my entire teaching strategy and class plan when this occurred. The positive feedback I've now received from the concept survey at the end of the semester is incredibly helpful. Otherwise, I am certain I would be feeling like I didn't do a very good job, which would lead to me becoming more unsure of myself and might actually make me a worse teacher. Now I am hoping that the opposite may occur.*

*I don't see how the SEI program could fail to be helpful to other new faculty in my position.*

In addition, the central SEI administered a formal web-survey of the faculty of involved departments concerning the SEI and how they view it and benefit from it. The data from this survey is currently being processed.

## **G. Advisory board input**

In addition to central SEI staff, the SEI advisory board includes:

Lorrie Shepard, Dean of the School of Education  
Stan Deetz, Professor of Communications



Clayton Lewis, Professor of Computer Science  
Mary Ann Shea, FTEP Director  
Robert Parson, Professor of Chemistry and SEI faculty liaison  
Dale Mood, Professor of Integrative Physiology and SEI faculty liaison  
Bill Wood, Professor of MCDB and SEI faculty liaison  
Sandra Laursen, CARTSS (Evaluation)

Over this past year, the advisory board has provided valuable discussions on several key areas, including: the evaluation of the success of the SEI, rate of progression through courses and how to know when work on a course is complete, and finding an appropriate balance of STF time spent on research versus implementation.

### **III. Budget summary**

A summary of the budget expenditures for Jan 2007 – Dec 2007 is provided here.

A more detailed budget, including expenditures for each of the departments, can be found in Appendix A. The expenditures essentially match the \$1,000,000/year funding, but because of varied timing in transfer of funds, this calendar year shows 2 years of money from the President's office, hence the extra \$500,000.

### **IV. SEI in Chemistry**

#### **A. Departmental structure of SEI program**

##### 1. Proposal submission process

The faculty devoted a portion of their Department meeting on November 16, 2005 to a discussion of the opportunities presented by the SEI. The faculty agreed that the current course format is not effective at educating our students, and that it is essential to explore new approaches. A small group of faculty was directed to prepare a proposal to the Initiative.

##### 2. People:

Faculty Liaison: Professor Robert Parson.

Chemistry Education Specialists: Dr. Laurie Langdon (all year), Dr. Thomas Pentecost (from 1 June 2007).

Faculty Working Group: see below.

##### 3. Departmental structures / decisions

Overall departmental oversight is provided by the Chair, Professor David Walba, and the Executive Committee, Professors Tad Koch, Veronica Bierbaum, James Goodrich, and Bruce Eaton. Senior Instructor Dr. Margaret Asirvatham is Director of the General Chemistry Program. The Undergraduate Curriculum Committee (Professors Walba, Bierbaum, Koch, James T. Hynes, W. Carl Lineberger, Amy Palmer, and Deborah Wuttke, plus Drs. Asirvatham, and Langdon) advises the Chair in matters involving new courses and course transformation. A General Chemistry Working Group was established in October 2006 to deal specifically with issues related to the SEI. Its present membership consists of Professors Parson, Bierbaum, Wuttke, and Veronica Vaida, together with Drs. Susan Hendrickson and Matthew Wise (instructors), Drs. Christine

Kelley and Lynn Geiger (instructors and academic advisors) and Drs. Langdon and Pentecost. This group meets on the average twice a month.

## **B. Course-related efforts**

### 1. CHEM 1111, General Chemistry 1.

#### a. Background

Chem 1111 is the standard beginning chemistry course for science majors and premedical students. With more than 1300 students per year it is not only the largest course in the department, but also the largest 5-credit course offered by the University. Most of these students take it during the fall term, when three lecture sections are offered, together with 40-45 recitation and laboratory sections overseen by 20-25 teaching assistants. In recent years the fall lecture sections have been team-taught, with one faculty member teaching all three sections for a portion of the semester, and then passing it on to another; all members remain actively engaged in laboratory, office hours, and examinations throughout the course. (During Spring and summer terms, a single lecture section is offered.)

#### b. Description of ongoing activities

##### i. Learning Goals.

In 2006, Dr. Asirvatham and Professor Bierbaum replaced the traditional course syllabus with a comprehensive set of detailed lecture-level learning goals. They also developed a set of nine broad, course-wide Learning Goals for CHEM 1111. In the spring of 2007 the Working Group refined these goals and suggested that one or two additional goals be added. In 2007, Drs. Parson, Langdon and Pentecost began to develop a set of topic-level goals that bridge the gap between the very broad course goals and the very specific lecture goals. Faculty were interviewed and one extended Working Group meeting was devoted solely to this exercise. By the end of the year the topic-level goals were about 50 percent complete.

##### ii. Learning Assessment: instruments and findings

The CLASS survey of student attitudes, which has been administered to General Chemistry students since beginning in 2004, has revealed that students perceive the subject to be non-intuitive, lacking in logical structure, and irrelevant to daily life. In spring 2006, Professor Katherine Perkins and Dr. Linda Koch, in consultation with Dr. Asirvatham, developed a Chemistry Concept Survey, based upon validated literature sources. This instrument has been revised in successive terms after faculty working group discussions. It was administered in both spring and fall terms of 2007. Learning gains were about 15% in the spring and 25% in the fall. Detailed examination of the results in various areas targeted by the survey suggest that compared to previous years, students have acquired more facility with translating chemical equations into physical pictures of atomic and molecular behavior, but also reveal some areas, such as thermochemistry, where conceptual learning appears to be minimal.

Because of the paucity of calibrated, validated quantitative assessment tools in Chemistry (a search of the literature revealed that essentially all of the surveys

that are currently used trace back to two research projects, one of which is still in progress), alternative measures of progress are needed. In the fall term, Langdon and Pentecost received HRC approval for a program of student interviews, and the first set were carried out towards the end of the fall term in both Chem 1111 and Chem 1131. The results of these interviews will be used both to improve the quantitative assessment instruments and to learn directly about the effectiveness of the various course transformation activities.

iii. Changes in course instruction

The Department began using clickers in general chemistry, as well as in other courses, in fall 2003, Examination questions have been revised, placing greater emphasis on concepts and molecular views of chemical events. In fall 2006 Dr. Langdon had developed a set of “Chemistry Concept Challenges” which target directly the key conceptual issues stated in the Learning goals and the misconceptions identified by the Concept Assessment and aim to help students make real-world connections to chemistry concepts. In fall 2007 Dr. Pentecost used these as the basis of a new set of Tutorial worksheets to be used by Teaching Assistants in the weekly recitation sections. The Tutorials aim to synthesize the conceptual issues addressed by the Concept Challenges with more conventional problem solving, with the goal of presenting students with a more unified perspective on chemistry as a science. Very preliminary results from a post-course administration of the Concept Assessment suggest that these strategies have yielded a meaningful increase in student ability to represent many chemical processes in molecular terms. Professor Parson will teach this course in Spring 2008, and will devote particular attention to probing for and addressing misconceptions in those areas, such as thermochemistry, that appear to dominate the low learning gains.

iv. TA training.

Because of the size of the class, Chem 1111 involves a large number of Teaching assistants. Most of these are first-year graduate students. These students have traditionally received a few days of TA training during their first week at CU, focused on such issues as laboratory safety, classroom management, and microscale teaching activities. In Spring 2007 the Working Group decided to extend this training period by three days to include a more thorough instruction in pedagogical fundamentals and interactive engagement approaches, as well as to better assess the TAs’ understanding of the course content. The Department paid for this program using a portion of its general chemistry course fees; only a portion of the entering graduate class went through the extended training, but this portion included most of the students who were to teach Chem 1111 in the Fall of 2007. Dr. Pentecost directed the program, and subsequent interviews of students and faculty yielded a strongly positive response. Dr. Asirvatham submitted a proposal to the National Science Foundation to support continuation and expansion of this program in subsequent years.

2. CHEM 1131, General Chemistry 2

a. Background

This is the successor to CHEM 1111. It is taken by approximately 800 students per year; students must pass CHEM 1111 with a grade of C- or better in order to register for CHEM 1131. The course covers a smaller number of topics in greater depth than is the case for CHEM 1111. Many of the general issues discussed above concerning CHEM 1111 apply to CHEM 1131 as well. Transformation of instruction in CHEM 1131 began in the Spring of 2007. Professor Parson taught both of the lecture sections offered in the Spring, as well as the single section offered in the Fall, and continued the emphasis upon peer learning and development of a molecular-level understanding of the chemical processes.

b. Description of ongoing activities

i. Learning Goals

The working group decided that the Course-Level goals originally developed for Chem 111 apply to Chem 1131 as well. Professor Parson attended the three-week Learning Goals workshop in Spring 2007. Professor Parson and Dr. Langdon began to develop Lecture-level and Topic-level Learning Goals for the course in November of 2006, and this process was about 75 percent complete at the end of the year.

ii. Learning Assessment:

A preliminary Concept Assessment Survey, based upon literature sources, was administered to CHEM 1131 students at the beginning and end of Spring Term and a revised version administered in the Fall. Since the number of validated questions available in the literature is very limited for the topics covered by this course, Parson and Langdon decided to focus the assessment on a single major topic, Chemical Equilibrium instead of trying to cover the entire course. This topic is widely regarded as one of the most difficult for students to learn. Results in Fall 2007 showed a normalized gain of about 30%; while this is hard to evaluate in absolute terms given the lack of comparison data, it clearly indicates that much more needs to be done. The results of student interviews carried out at the end of the fall term will be used both to validate the survey and to suggest strategies for targeting misconceptions.

iii. Changes in Course Instruction

The transformation of course instruction followed parallel paths in Chem 1111 and Chem 1131; only those aspects of the latter that differ from the former will be discussed here. Undergraduate Learning Assistants (LAs) were used during both terms, following two different models. In the Spring term, the LAs held weekly "Learning Groups" in which they helped students work through the Concept Challenges in small groups. This produced a positive response, but was cumbersome to manage and only about one third of the class was able to benefit. In the Fall, the Concept Challenges were converted into Recitation Tutorials (as in Chem 1111) and the Learning Assistants brought into Recitation to work together with Teaching Assistants in facilitating small-group work. This model was deliberately patterned after the Tutorials being used in the Physics Department. Two of the interactive simulations developed by the Physics Education

Technology (PhET) project at CU were incorporated into lecture and into recitation and homework activities.

### 3. CHEM 1151 and 1171, Honors General Chemistry

This course sequence is taken by students whose background and placement exams indicate an especially high level of preparation in high school chemistry, physics and mathematics. The course material roughly parallels that of CHEM 1111/1131, but with more detail and at a higher level. Approximately 40-50 students take the course each year. Professor Deborah Wuttke taught Chem 1171 in Spring 2007 and introduced clickers as well as some of the concept challenges. Professor Vaida followed similar strategies when she taught Chem 1151 in Fall 2007. The CLASS and Concept Surveys were also used in both classes.

### **C. Departmental faculty development and involvement in SEI efforts**

To this point, Faculty from the Department have been involved in SEI activities either on an individual basis (as instanced by many examples above, e.g. participation of several faculty in the SEI Learning Goals workshop) or through the Working Group. During the 2007 calendar year a large fraction of the faculty's time and energy was devoted to Program Review, which left less time than for department-wide discussions of course transformation than had been anticipated. Now that Program Review has been finished, the SEI Chemistry personnel plan to make a presentation to the Department faculty during the Spring term.

### **D. Synergistic activities by SEI personnel**

During the past year, the personnel associated with the SEI have engaged in a variety of activities related to Chemistry Education. Dr. Langdon participated in the development of the American Chemical Society's bank of Conceptual Examination questions. (The ACS gave the participants in this program Dr. Pentecost presented his research on the use of textbooks by general chemistry students to the May 2007 First Year Chemistry Instructor's conference at CU Boulder, and to the October 2007 conference for high school chemistry teachers. Langdon and Parson attended the Gordon Conference on Chemistry Education in June 2007 (at which Langdon presented a poster describing the SEI activities in chemistry). Finally, Dr. Langdon hosted a one-day introductory workshop for the POGIL (Process Oriented Guided Inquiry Learning) project, an NSF-sponsored program that promotes the augmentation or replacement of traditional lectures by research-based guided inquiry activities. The workshop was attended by Parson, Hendrickson, Pentecost, and several of the SEI teaching fellows from other CU departments, as well as a large number of secondary and post-secondary instructors from schools and colleges in Colorado.

### **E. Goals for 2008**

1. Complete the development and revision of learning goals, both broad and specific, for CHEM 1111 / 1131.
2. Continue work on constructing, revising, and validating concept surveys by conducting and analyzing student interviews. The Concept Surveys, the collected written student responses to the Concept Challenges, and student interviews constitute a body of data that can be analyzed to provide information about what students are learning and about the effectiveness of the various strategies that have been introduced to improve student learning.

3. Collect and analyze data to assess the added value of using Learning Assistants in CHEM 1111 / 1131. Continue to study the integration of LA's and TA's in recitation sections. LA's are being used together with TA's in CHEM 1111 recitations for the first time in Spring 2008. The combined use of LA's and TA's requires well-developed materials that encourage group work and training for LA's and TA's in how to effectively engage and support students. A compendium of such materials now exists, but the experience of more established tutorial projects (such as the University of Washington Physics Tutorials) strongly suggests that several years will be required to optimize them. Student interviews will play a significant role in this process.
4. Extend the highly successful enhanced TA training program developed in summer 2007 to four days (from three) and involve a larger proportion of the entering graduate students in the extended program.
5. Begin SEI involvement in chemistry courses for nonscience majors. The first course selected is Chem 1031, Environmental Chemistry II. This is the second term in a one-year sequence intended primarily for those Environmental Studies majors who choose the "policy" track of that program (ENVS majors who choose the science track take the standard sequence 1111/1131). Since ENVS is one of the most popular majors in the College of Arts and Sciences, these courses represent a major fraction of the Department's contribution to service teaching. Professor Margaret Tolbert, who is teaching the course in Spring 2008, is using clickers and has requested SEI assistance in revising course materials. Since the current SEI personnel are already heavily committed for Spring 2008, it was decided to focus SEI efforts upon a single topic area – the greenhouse effect and global warming – where materials (including PhET simulation) that have been developed for classes in the Physics Department might be adapted for use in Chemistry. If this is deemed successful, a more thoroughgoing transformation of the entire year-long course sequence is on the table for consideration.
6. Begin SEI involvement in upper division courses. The first course selected is Physical Chemistry I, Chem 4511, which Parson will teach in the Fall of 2008. Parson is considering replacing one of the three weekly lectures with a class activity based upon the published POGIL (Process-Oriented Guided Inquiry Learning) materials. Parson will also use three hands-on activities developed specifically for this course by Chemistry graduate student Jack Barbera (prior to establishment of the SEI).
7. Collect, evaluate, and archive course materials for Chem 1111/1131. Over the past few years the instructors for this sequence have developed a large number of novel class materials – clicker questions, recitation tutorials, and conceptual examination questions. They have shared these materials informally with each other, but have not established a standardized archive. The Chemistry SEI team intends to organize and evaluate these materials in a more systematic fashion during the year 2007. Proposed evaluations include classifying clicker and exam questions according to Bloom's taxonomy, and examining student response patterns to clicker questions.

## **V. SEI in Geosciences**

### **A. Background**

In November 2005, the Department of Geological Sciences elected to participate in the SEI by a vote of 17 to 2 with 2 abstaining and 7 absent. Professor David A. Budd volunteered to coordinate efforts within the Department and to be the faculty liaison to the SEI. Dr. Budd serves on the Center's advisory board and supervises the Science Teaching Fellows (STFs) in Geological Sciences working on the project.

## **B. Human Resources**

Two post-doctoral STFs were hired in the spring of 2006 and began working on the project in August, 2006. By January of 2007, it became clear that a 3<sup>rd</sup> STF would be needed in order for the Department to achieve its goals. In Geological Sciences, up to 8 different faculty teach up to 3 different introductory non-major courses each semester and supporting even half of these individuals effectively and efficiently was impossible for just 2 STFs. The 2007 budget was adjusted for a 3<sup>rd</sup> STF rather than continue with two 50%-time graduate teaching assistants. A search committee was formed, a national search was conducted, and Dr. Leilani Arthurs was ultimately selected from a pool of 11 applicants. Dr. Arthurs accepted the position and started in July, 2007.

## **C. Implementation Strategy**

The Department is implementing the SEI in two stages. The initial focus is on 1000-level courses and upper division non-major A&S core courses. These courses generate ~8100 student credit hours per year, and almost half of our 30 tenure-track faculty teach one of these courses in any one year. Thus, focusing first on these introductory courses will have the greatest immediate impact on students and faculty. The second stage of implementation will focus on our major-track courses, although a few faculty are already working parts of the initiative into those of courses.

In January 2007, the assignments of the three STFs were restructured to optimize communication and working relations between them and the faculty. Dr. Andrea Bair works with all faculty involved in our largest introductory course, GEOL 1010 (structure, composition, and processes of the Earth). Dr. Jennifer Stempien works with the faculty involved in the two other introductory courses, GEOL 1020 and 1060 (history of the Earth, life, oceans, and climate) and is responsible for developing the Geoscience's version of the students' attitudes survey. Dr. Leilani Arthurs assists those faculty teaching courses related to environmental geosciences (e.g., ENVS 1000; GEOL 2100; GEOL 3070).

## **D. Highlights of 2007 Achievements and Activities**

Overview:

1. Eight of nine instructors of GEOL 1010 implemented aspects of the SEI in their sections, with 5 of those instructors attempting multiple aspects of the initiative (learning goals, in-class activities, changes to homework, etc).
2. The three instructors that taught our 3 sections of GEOL 1020 also implemented multiple aspects of the initiative in their sections (learning goals, in-class activities, changes to homework, etc).
3. One instructor who taught 2 sections of GEOL 1060 also attempted aspects of the SEI in his course --- definition of learning goals and consideration of how clicker questions, homeworks, and exams aligned with those goals.

4. One instructor who taught 1 section of GEOL 2100 was very successful in implementing learning goals, a concept inventory, concept-orientated homeworks, and in-class activities.
5. The two instructors who teach the 2 sections of GEOL 2700 (majors track, Introduction to Field Geology) wrote learning goals for this course. As it is a practical course involving observation and problem solving using student-collected field data, all other aspects of the course were already aligned to the SEI.

Details:

1. In the Spring of 2007, all faculty involved in the two introductory courses that are taught most often (Physical Geology & Earth History) worked in two separate working groups, each with a separate STF, to define consensus learning goals. Both working groups culminated their efforts with separate 3-day workshops in late May and early June in which initial course-level goals for each course were finalized. Subsequently (i.e., Fall 2007), some (but not all) of the instructors of these courses utilized some or all of these goals and expanded them to unit- and lecture-level goals. However, the lack of learning-goal use and collaboration between all GEOL 1010 instructors remains an obstacle for significant progress in that course. These barriers do not exist for the 1020 course; all of its instructors are collaborating with each other and pledged to use learning goals.

2. Two types of new homework strategies were evaluated for GEOL 1010.

In the spring term, 6 concept challenges, as used in Chemistry, were created and assigned to two sections. Voluntary help sessions were also provided as this course does not have a recitation or lab. Student's were surveyed and interviewed to assess what they thought of these challenges and to determine what they learned from them. The STFs also benefited as they learned about student thinking via help sessions. The challenges clearly increased students' problem-solving skills and there was greater improvement in concept comprehension relative to sections not using these homeworks. But a large amount of time was spent by the STFs to develop the challenges and train peer TAs to staff the help sessions, and the faculty involved did not always align the challenges with classroom activities, their lecture, or their exams. So this approach to homework was judged to have great potential to improve learning but is probably not sustainable within the organizational constraints of GEOL 1010 (no recitations or TAs assigned to any section).

In the fall term, 3 different instructors (Drs. Lon Abbott, Matt Pranter, and Becky Flowers) collaborated to develop more concept-oriented homeworks that they administered through CULearn, and these 3 also developed and implemented 6 in-class activities related to key concepts that they each taught. This group of 1010 faculty took full responsibility for the design of these exercises, for linking them to their written learning goals and their lectures & assessments. Surveys and interviews by the STFs showed that students demonstrated a better understanding of concepts and reported the in-class activities to be highly useful and enjoyable. Faculty valued them and found them useful vehicles for them to learn about student thinking. The 3 faculty that developed these exercises will do it again; we hope to entice other 1010 faculty to try this approach in 2008.



3. The physical geology concept inventory for GEOL 1010 was administered to all 9 sections taught in 2007. Validation of ten questions on the inventory is nearly complete and validation of 5 more is progressing. Results show an average learning gain of ~34% learning gain in 1010, with very high gains on some concepts (>70%), others with lower gains (< 20%) and lots of variations between different instructors. The 5 sections that used either concept-challenge homeworks or in-class activities had higher average gains than the 4 that did not (~42% vs. ~24%), even though the vast majority of the validated questions do not directly relate to the subject matter of those interventions. These results provide a snap shot of student learning in 1010 when the only SEI innovation that is widely applied is use of clickers. Getting a greater percentage of the 1010 faculty to try other types of interventions remains a problem.
4. At the request of two instructors that team-teach two sections of 1010 (Drs. Greg Tucker and Eric Tilton), an experiment was run in Spring 2007 on the use of clickers versus a show of hands for the same, in-class conceptual questions. In interviews and surveys, the students confirmed what the literature already stated – the anonymity and accountability of clickers make them a better tool from a students' point of view.
5. More than 30 interviews of 1010 students and a thorough search of the education literature resulted in the identification of 28 common student misconceptions in GEOL 1010 and an additional 17 concepts that are difficult for students to learn. These were communicated to the Geoscience faculty and will be explored in more detail in 2008.
6. Classroom observations indicate that some GEOL 1010 instructors are using clickers effectively to elicit student reasoning and confront misconceptions; however many are still not using clickers effectively and it remains a challenge to move clicker use beyond attendance and assessments of low-level cognate thinking.
7. The design document for the initial interactive simulation for the Geosciences (on glaciers) was finalized and this simulation is in production. No additional simulation work was undertaken - ideas were discussed, but moving them to design stage awaits assessment of the yet unfinished glacial simulation.
8. In the spring of 2007, GEOL 1020 sections were used to assess what type of learning difficulties students were having (done via observations and interviews). Five key concepts were identified that can affect student's understanding of material throughout the term (erosion vs. deposition; relative ordering, applications of absolute dating; carbon cycling; immensity of time involved in ancient events like landscape development, mountain building, & climate change). It was also found that students consider 1020 to be more orientated toward problem solving, but also less useful to them than GEOL 1010.
9. Dr. Budd's fall section of 1020 section was the first to restructure the course as per the plan developed by all 1010 faculty in their June retreat. The goal is to orient it so that material is presented much like a geoscientist would work – moving backward through Earth history from the better know to the lesser know, a case-study approach that is problem orientated, and development of tools & concepts as needed to solve problems.

10. An initial concept inventory for GEOL 1020 was developed and administered in the fall term. The results are still being processed.
11. Classroom observations of the 3 GEOL 1020 sections found that the majority of students are more engaged when material is presented in a way that relates to their out-of-class experiences or is presented as in-class demonstrations. Most students do not exhibit traditional “active” behavior such as note taking and asking about lecture material they are uncomfortable with.
12. Dr. Scott Lehmann taught two sections of GEOL 1060 in 2007 and worked with an STF to: define and refine learning goals; align lectures to match goals; redesigned clicker assessments so that they matched goals and were used to effectively explore student understanding of concepts (clickers now achieve this far better in 1060 than in 1010); develop 6 new concept-based homeworks; and identify concepts on which to build future in-class activities.
13. Dr. Alexis Templeton offered a new course, GEOL 2100 (Environmental Geology, a non-major general science class) and she defined and implemented learning goals, a concept inventory, concept-orientated clicker questions, and numerous in class activities. An STF supported her efforts through classroom observations, student interviews, mapping student note-taking, mapping student-faculty interactions during discussions, and bi-weekly consultations with Dr. Templeton about goals and classroom instruments. As this course is only taught by Dr. Templeton, it is now probably the course in the Geosciences that is most advanced in terms of full implementation of the SEI goals.
14. The CLASS-Geology survey, which measures students’ attitudes and self-efficacy toward science, was further developed. Interviews were conducted to determine what terms were appropriate for converting the CLASS-Physics tool to geology, as well as for 5 new question on the nature of science in general and 5 new questions on how students conceptualize geology,
15. The attitude survey was run in 9 introductory sections during 2007, and the analyzed results were reported to departmental faculty. Key results: (1) establish a baseline view for faculty of student attitudes when they enter & complete introductory geology courses; (2) identify certain attitudinal aspects of the course that faculty could/should consider.
16. The attitude surveys also indicate that students view introductory geosciences quite differently than physics or chemistry (favorably --- geosciences are of more general interest; unfavorably --- geosciences are not really scientific, have no (true) experimentation, and are all descriptive), which presents challenges (and opportunities) for the Geoscience faculty in general and the SEI initiative in particular.

Other items:

1. At the end of the year, the STFs completed two short “white papers” on the cumulative results of Fall 2006 through Fall 2007 activities. These reports on Conceptual Learning in Geology Courses and the Importance of Considering Student Attitudes have been distributed to the faculty for use in the Spring 2008 term.

2. Plans to develop a departmental web site for sharing info were halted in lieu of the SEI's effort to develop a template for such a system with more sophisticated user interfaces and search protocols than Geological Sciences had planned. Beta testing of the SEI resource data base template began in December 2007 using Geol 1010.
3. Professional development of the STFs is evidenced by their presentation of 5 papers at the annual Geological Society of America meeting, their being asked to review proposals for NSF, and invitations to speak at professional meetings and teacher training workshops.
4. A collaborative proposal to the NSF was prepared and submitted with Jennifer Stempien as PI and David Budd as Co-PI. The proposal involves collaboration with 10 other schools (community colleagues, private 4-year colleges, comprehensive universities) to: 1) use a common instrument to investigate how aspects of the affective domain, in particular student motivation, vary for students in introductory Geoscience courses at a range of institutions; and 2) identify if and how those aspects vary with instructor, learning environments, and class characteristics.

#### **E. Goals for 2008**

1. GEOL 1010:
  - a. Confront the still erratic development and adoption of learning goals by the various 1010 instructors. This will be done by defining the common themes in the goals written by those who have done so, merging those into the draft course-level goals defined by the group in their May 2007 workshop, and then trying to entice those who have yet to define or implement learning goals at any level to try those that their peers have adapted.
  - b. Continued focus on developing concept-based homeworks for all material; trying to expand concept-based homeworks and the in-class activities to more sections (i.e., get more instructors to buy in); and expand effective use of clickers in general so there is less lecturing and more thinking.
  - c. Continue efforts to improve and focus the 1010 concept inventory so that it is a tool that measures the concepts faculty truly want measured, and thus the faculty will want to use it.
  - d. Prepare a "white paper" that provides more information to the faculty regarding student misconceptions and learning difficulties that have already been identified, and suggest specific teaching strategies to help students confront those problems. Recruit one or more 1010 instructors to aggressively test those strategies in the fall.
  - e. Incorporate the first interactive simulation (on glaciers) into a fall 1010 section and evaluate its effectiveness through student interviews.
  - f. Initiate a project to evaluate how 1010 students employ scientific thinking and critical thinking to solve problems of a scientific nature. The collaborating faculty member interested in this project has heretofore declined to implement any aspects of the initiative.
2. GEOL 1020:

- a. Develop the concept inventory further by interviewing students, assessing results from Fall 2007 and preparing a 2<sup>nd</sup> version that can be employed by Fall 2008. This requires faculty to provide more input on what concepts should be included/excluded, what are their expert-like answers, what novice-like responses they want included.
  - b. The two faculty teaching in spring 2008 want to try to improve homeworks – offering them more often but with fewer questions per homework, and making sure they align to key concepts and learning goals.
  - c. In both the spring and fall, 1020 instructors will continue working on restructuring the content of each instructor’s lecture material so as to focus case studies and moving backward through Earth history as described above.
  - d. At end of spring term, a compilation of case studies that have been developed to that point will be compiled for use/consideration by Fall 2008 faculty.
  - e. Compilation of learning goals used by Fall 2007 and Spring 2008 faculty will be done, and an assessment of those detailed goals in terms of the June 2007 workshop-defined goals will be undertaken.
3. GEOL 1060:
- a. A different instructor is doing the course in the spring of 2008 and his goal is to simply integrate clickers into his version of the course. The course will not be taught in fall 2008
4. For Environmentally-related Geoscience courses:
- a. STFs will work with Dr. Tom Marchitto to develop a complete set of learning goals for GEOL 3700 (Introduction to Oceanography) and develop a draft concept inventory. Classroom observations and discussions with Dr. Marchitto will consider what type of activities can be implemented in Spring 2009 (use of clickers, in-class activities, revisions to homeworks).
  - b. Compilation of all interview and survey data collected in Fall 2007 in GEOL 2100 (Environmental Geology) will be completed and a report for the instructor (Dr. Alexis Templeton) will be prepared. The report will focus on relations between defined learning goals, initial concept inventory, and all the assessment data collected on class participation, effectiveness of clickers, in-class exercises, homeworks, student-teacher interactions, etc. Report will include recommendations to Dr. Templeton for Fall of 2008 on improving learning goals, clicker use, concept inventory content, and expanded in-class activities.
  - c. STFs will work with University of British Columbia Earth Science program on modification of the CLASS survey so it assesses student attitudes in introductory Environmental Sciences (e.g., ENVS 1000, which is taught by Geoscience faculty at CU-Boulder).
  - d. An attempt will be made to recruit instructors of other non-major A&S core courses (e.g., GEOL 3500 - Earth Resources and the Environment and GEOL 3950 - Natural Catastrophes & Geologic Hazards) to begin implementing the

initiative in their courses (learning goals, alignment of those goals with homeworks, in-class activities, & exams).

- e. Support development of the Department's new majors-track in Environmental Geosciences by working with faculty to define learning goals and key concepts as they prepare new course proposals.

## 5. Other

- a. Dr. Arthurs will continue working on a science versus pseudoscience project, which is designed to look at how different in-class activities influence how students think about science, problem-solving skills, and attitudes about science vs. pseudoscience (collaboration with Douglas Duncan in APAS).
- b. Once the beta-testing of the GUI for a data sharing repository is completed by the SEI, we hope to be able to upload materials for the faculty's use in the Fall of 2008 (GEOL 1010, 1020, and 1060).
- c. Design a 2<sup>nd</sup> interactive simulation (probably) on relative ordering of geologic events as this could be utilized in both 1010 and 1020 and multiple faculty have expressed an interest in it.
- d. Interviews and a survey of students in an upper division majors-track course will be made concerning learning difficulties with concepts related to erosion versus terrestrial deposition of sediments. The goal will be to better understand the difficulties and interventions that might overcome those difficulties.
- e. Development of the attitude survey will continue with (1) completion of the statistical evaluation of how questions are being categorized (i.e., do categories established for CLASS-Physics work for Geology), and (2) interviews of students to finalize questions on the differences in student attitudes towards Geology versus other physical sciences, and (3) compilation of survey results for at least one upper division majors-track course to assess if majors (i.e., more expert like students) do indeed choose more expert-like responses as the survey assumes.
- f. The revised version of CLASS-Geology (i.e., v 2.0) will be ready for fall 2008 – it will be a fully validated and categorized survey, although it may still not assess everything that we might like to assess. This 2<sup>nd</sup> version would be one that can be used thereafter without additional revision, which would allow STF time to be reallocated.

## **VI. SEI in Integrative Physiology**

### **A. Departmental structure of SEI program**

#### 1. Proposal process

Information about the SEI was distributed to the IPHY faculty at the departmental faculty meeting on October 12, 2005. On the basis of the resulting discussion it was decided to ask Professor Wieman to attend a future faculty meeting. Professor Wieman was present at the November 2, 2005 faculty meeting and he made a brief presentation followed by a question and answer period. At a meeting held on November 30, 2005 the faculty discussed the notion of submitting a proposal to participate in the SEI. The

faculty voted unanimously to do so. Chairman Roger Enoka drafted a proposal that was subsequently edited by several faculty members and then submitted on December 8, 2005.

## 2. People

- a. Faculty Liaison: Dale Mood
- b. STFs: Francoise Benay, Sarah Kennedy (half time), Katharine Semsar

## 3. Departmental structures

- a. There is a curriculum committee which looks at the curricula of courses in the department, and if needed offers suggestions or comes up with alternatives for what is currently in place.
- b. Since the department has been involved with the SEI, the IPHY department has been working to restructure the degree requirements for the IPHY undergraduate major.
- c. New physiology course

Faculty in the IPHY department made the decision to move from a one semester introductory physiology course to a two-semester upper-division course. The STF's helped design the new coursework to align with course learning goals. This process has been ongoing over the past year. A lot of work was done by the STFs and faculty in the department to design this new course:

- i. The STFs interviewed faculty to identify key concepts. After identifying the key concepts for the new course, the STFs worked closely with the curriculum committee to focus the course content around these key concepts, and to choose appropriate lab topics and how best to align them with the two-semester major and one-semester non-major course. They also worked with the committee to determine where the new two-semester course and laboratory sections best fit into the major course schedule as a prerequisite to upper-division courses. The STFs also reviewed current physiology texts available, which led to a change from a reference textbook to a text appropriate for student learning.

## **B. Course-related efforts**

### 1. IPHY 1010: Introduction to Physiology (Spring 07) & IPHY 3470: Physiology 1 (Fall 07)

A total of 216 students were served during the work on this course: 161 students in IPHY 1010 during the spring 2007 semester, and 55 students in IPHY 3470 during the fall 2007 semester. There was one faculty member involved with the course in each the spring and fall semesters. During the spring semester, there were three TAs involved with the course, and there was one grader during the fall semester.

Through spring 07, the course was still IPHY 1010; as of fall 07, the course officially became IPHY 3470, Physiology 1, the first semester of a two-semester course now being taught at the 3000 level in the department. The lab is offered concurrently with the Physiology 2 course (IPHY 3480).

### **Ongoing activities:**

- a. Improving learning goals
  - i. Ongoing revision and assessment of these learning goals
  - ii. Developed materials to aid student learning of these goals, including clicker questions in spring 07 and clicker questions and homework fall 07
- b. Refining an assessment tool
  - i. An assessment tool was created, composed of 37 multiple choice questions. The assessment tool was administered during the first week and last week of the course.
  - ii. Throughout the spring 2007 semester revisions were made to increase the number of conceptual-based questions over testing factual knowledge. To learn how students are reasoning, what misunderstandings exist, and what students do not know at this level, we tried to create improved answer choices (distracters and correct answers for right reasons). To help us come up with these choices we held peer help sessions and performed student interviews.
  - iii. During the fall 07 semester we kept the pre/post assessment as it was designed for the spring 07. The course has changed so much that we believed it was important to keep that constant, and through results on homeworks, clicker questions, student questions and discussion, we could collect additional information on how to revise the Physiology Pre/Post test now that the class is an upper division course.
- c. Understanding student learning and thinking
  - i. Evaluation of students' homeworks, student questions and discussion from clicker questions given in class by instructor were used to evaluate student learning and misconceptions.
- d. Changes in course instruction
  - i. Five homework assignments were introduced in fall 07. One each for the five main physiological systems presented in this course: Cell Physiology, Neurophysiology, Muscle Physiology, Endocrinology, and Immunology.
  - ii. To engage students in discussion, the course instructors for both semesters began to introduce 3-4 multiple choice questions using the i-clicker system throughout the lectures. These questions were used to emphasize key points from previous lectures, to review, or to examine areas of difficulty discovered from previous interviews, homeworks, and quizzes given in the last three semesters.
  - iii. Ideas for clicker questions and homeworks resulted from STF readings in *The Journal of American Physiology of Education*, "How People Learn", peer help sessions, previous quizzes, student interviews, student surveys on learning, discussions with faculty to connect course material to current research in physiology and to pedagogical tools, student discussion, student questions,

problem based learning websites, and current literature in various scholarly journals and newspapers.

e. Faculty resources

- i. A hard copy binder for the course was developed to be used, improved, and modified by instructors and to be used as a tool for instructors in future years the course is taught. This includes primary physiology education literature, learning goals, potential clicker questions, identified misconceptions, level of knowledge with which students are entering the course, worksheets/activities for peer help sessions, homework, surveys, assessment tool, and quiz questions.

2. IPHY 3410-Human Anatomy Lecture

Throughout the work on this course in the fall 07 semester, there were a total of 500 students served. Two faculty members were involved with this course. There were no TAs involved with this course during this semester.

The STFs started working in anatomy in Summer 07 by sitting in on classes and documenting student questions. In Fall 07, STFs started working more directly with faculty in various capacities (see below) to change the course.

**Ongoing activities:**

a. Improving learning goals

- i. Learning goals have been developed with input from all three faculty who teach anatomy. The STFs provided input on the development of materials to aid student learning of these goals.
- ii. During the Fall 07 semester, instructors developed their own clicker questions and the STFs provided feedback and question suggestions.
- iii. The STFs have been providing feedback on exam questions (clarity, alignment with learning goals).

b. Developing an assessment tool

- i. An assessment tool was developed by the anatomy instructors with feedback from SEI. This assessment tool is composed of 10 multiple choice questions with spaces for explanations, and was administered the first and last week of the course.
- ii. Students were asked to explain their answer choices on the pretest. These data will be used to validate the current question set, develop improved distracters, and document common student misconceptions of students entering the course. The post-test will include approximately 10-15 additional questions for validation before inclusion on the pre/post test in Spring 2008.

c. Understanding student thinking and learning.

- i. In order to help understand student thinking, the STFs have been documenting student questions and responses to oral questions during class time. They have also been looking at student responses to clicker questions and responses to open-ended questions on the pre- / post-assessment tests.



- ii. Student interviews: Following each of the three mid-semester exams, we have developed an open-ended content-based interview aligned with both the major learning goals from that section of the course and common wrong answers on exam questions (all exams are multiple choice). Interviews also include questions about student's approaches to studying the material. The STFs have interviewed 32 students.
  - d. Changes in course instruction
    - i. During the past year, clicker questions have been introduced. Ideas for clicker questions have come from faculty members prior experience and the clicker question bank provided with the textbook.
  - e. Developing resources for faculty
    - i. Weekly meetings have been held with current anatomy faculty to provide feedback on the ongoing development of learning goals and clicker questions. The major ideas discussed during each meeting was documented (including common student misunderstandings of that week's topic).
    - ii. Both an electronic and hard copy binder for the course was developed to be used, improved, and modified and to be used as a tool for instructors in the future years the course is taught. This will include primary physiology education literature, learning goals, clicker questions, common student misconceptions, knowledge level of students entering the course, potential questions for future homework sets, pre/post assessment tool, and exam questions.
    - iii. Students' study habits and abilities to integrate material on their own were documented for faculty to use in requesting TAs for the class. Anatomy faculty wish to add either a recitation section or at least homework assignments to help guide students in how to integrate information in the course as well as add grading support to allow them to ask open-ended exam questions. They hope to use this documentation of students' difficulties in integration as support for these additional course resources.
  - f. Terminology workshops
    - i. Bi-weekly hour-long sessions were held where students learn to use word roots, prefixes, and suffixes. This semester has included separate groups using more of a repetition to build familiarity vs. more contextual exercises. These have potential both as continued voluntary sessions and as homework assignments.
- 3. Other courses with some involvement

Due to interest generated by the department's involvement in the SEI, additional projects have been developed in the following courses.

- a. IPHY 2800 Statistics
- b. IPHY 3420 Human Nutrition and Performance
- c. IPHY 4440 Endocrinology

- d. IPHY 4600 Immunology
- e. IPHY 4650 Exercise Physiology
- f. IPHY 4720 Neurophysiology
- g. IPHY 2800-Statistics
  - i. Development and implementation of a pre/post assessment tool
  - ii. Use of clickers
  - iii. Development of a research question and intervention for Spring 2008
- h. IPHY 3420 Human Nutrition and Performance
  - i. Use of clickers
- i. IPHY 4440 Endocrinology
  - i. Addition of a recitation to the lecture
  - ii. Implementation of concept maps in recitation.
  - iii. Administration of an end of term survey
  - iv. Piloting clickers
- j. IPHY 4600 Immunology
  - i. Development of a recitation section that will incorporate active learning and peer instruction with key concepts
  - ii. Development of clicker questions
  - iii. Development and revision of key learning goals to streamline content covered in the course
- k. IPHY 4650 Exercise Physiology
  - i. Development and implementation of clickers in lecture
  - ii. Administration of an end of term survey
  - iii. Implementation of concept maps
- l. IPHY 4720 Neurophysiology
  - i. Development of course goals
  - ii. Development of a preliminary assessment tool
  - iii. Development of clicker questions
  - iv. Development of recitation activities in addition to existing lab
  - v. Administration of an end of term survey

**C. Other SEI activities**

1. Developing resources for faculty
2. Held faculty brown bags with the following topics:

- a. Creating a valid and reliable assessment tool
  - b. Round table on how clickers are going for faculty and what is working or not
  - c. Using concept maps
3. CLASS (Colorado Learning Attitudes about Science Survey)
- a. The IPHY SEI is collaborating with the MCDB SEI to administer Bio-CLASS to classes across biological disciplines.
  - b. During the summer of 2007, three faculty meetings were conducted to revise the CLASS questions to make them more relevant to the field of biology. After the questions were revised, approximately 12 student interviews were conducted to validate the Bio-CLASS tool. The Bio-CLASS was then revised based on problems identified during student interviews.
  - c. The revised Bio-CLASS was administered to approximately 2000 biology students across biology departments at CU during the fall '07 semester, including both IPHY 3410 (Anatomy) sections consisting of approximately 500 students.
  - d. The revised Bio-CLASS was given to experts in biology across multiple departments and campuses; 80 responses were received.
4. TA training
- a. Monthly brown bags are provided for TAs concerning common pedagogical theory and tools: 4 in Fall '07, 3 additional planned for Spring '08. The brown bag topics in Fall '07 included: misconceptions, metacognition, cognitive load, and tools to help students synthesize course material.
  - b. The department lead TA will help the SEI make a binder of all the materials for the brown bags, including learning goals, readings, activities, and discussion topics. This TA Brown Bag Binder will go to next year's lead TA for that person to run similar brown bags.
5. Several members of the IPHY SEI attended the Teaching and Learning Course (Mood, Benay, Semsar) and several attended the National Academies Summer Institute (Semsar, Kennedy, Byrnes). These allowed for development of teachable tidbits specific to physiology, as well as increased pedagogical education. From this, we increased TA training and graduate student mentoring in physiology education

**D. Departmental faculty development and involvement in SEI efforts**

- 1. Faculty involved in leading SEI efforts: Dale Mood
- 2. Faculty involvement in workshops/brownbags:
  - Janet Casagrand, Ruth Heisler, Owen Murphy, Roger Enoka, Monika Fleishner, Kenneth Wright, Bob Mazzeo, Bill Byrnes, Dale Mood, Roger Enoka, David Norris
- 3. Faculty input through interviews/feedback on goals, assessment questions, etc.

David Allen, Roger Enoka, Janet Casagrand, Monika Fleshner, Dale Mood, David Norris, Kenneth Wright. Rodger Kram, Adam Hayes, Christopher Lowry, Pei-San Tsai, Christopher DeSouza, Ruth Heisler

4. Faculty Partnering with SEI STFs:

Spring 2007: Kenneth Wright

Fall 2007: Adam Hayes, Pei Tsai, Chris Lowry

Spring 2008: Bill Byrnes, Cynthia Carey, Ruth Heisler, Kenneth Wright

**E. Goals for 2008**

1. Continue to refine 1<sup>st</sup> semester physiology assessment tool and to be a resource for clicker questions and assignments
2. Continue adding to and improving IPHY pedagogy binder
3. Converting Physiology Pedagogical Binder into a departmental online resource
4. Creating of Simulation Modules to crossover with Introduction to Biology
5. Refining anatomy clicker questions and assessment tools. Potentially pilot homework to be graded off-site
6. Refining learning goals for second semester physiology. Development of a pre/post-assessment tool for second semester physiology. Development of homework, clicker questions, and providing feedback for exam questions.
7. Experiment in IPHY 2800 to investigate if method of assigning students to work group affects learning.
8. Refine homework assignments in IPHY 3470
9. Analyze results of Bio-CLASS

**VII. SEI in MCDB**

**A. Departmental structure of the SEI program**

The departmental structure of the SEI program is unchanged. Drs. Jia Shi and Michelle Smith are employed as Science Teaching Fellows. Dr. Jennifer Knight is the MCDB SEI coordinator, and Dr. Bill Wood is an advisor for the program. The only addition is a working group that meets approximately once a month to exchange ideas. This group consists of all SEI-related personnel, and most professors that are working directly with STFs.

**B. Course-related efforts**

1. MCDB 1150

Introduction to Cell and Molecular Biology (MCDB 1150) is offered every fall. The typical enrollment is approximately 400 students. Dr. Jennifer Martin and Nancy Guild taught the 400-student course. Dr. Quentin Vicens taught an additional small section of this course for the Baker Residence Hall Program (24 students). The same course materials were used in both classes, including problem sets and exams. Dr. Jia Shi (STF) continued working with this course in the fall 2007 semester.

- a. Development of learning goals for the course

During the spring 2007, Jia Shi worked with Michelle Smith and Bill Wood to modify the course learning goals that were used in the last fall semester. MCDB offers another introductory course, Biofundamentals (MCDB 1111), taught by Dr. Mike Klymkowsky every spring semester. Since the content emphasis is different from MCDB 1150, it was important to agree on a set of common course and topic learning goals for both courses. After several iterations, a common set of goals were agreed upon by the teaching faculty for these two courses; these goals will be used for the foreseeable future.

b. Development of an assessment instrument to measuring student learning

Last year, we developed a preliminary Introductory Biology Assessment Tool, which was administered to the Intro students for the first time in fall 2006. Student answers helped to reveal some misunderstandings and difficult concept areas, and also revealed flaws in the assessment tool. To improve the assessment, Jia Shi conducted two rounds of student interviews during the spring and summer 2007. The purpose of the first round of student interviews (n=13) was to get student feedback on the pre-post assessment we developed and used in the fall 2006 semester. Based on this feedback and the new common course learning goals, the assessment was completely re-written. The new assessment 1) removed questions that were too easy (question on which the average pre-assessment score was >90%), and 2) reworded questions that include scientific jargon. A second round of student interviews (n=12) were conducted by Jia Shi in conjunction with the process of re-writing the questions. These interviews helped provide better distracters for incorrect answers (the new distracters were primarily taken from student's incorrect answers to open ended questions), and prompted the addition of new questions that address students' difficult concept areas. Finally, the assessment questions were aligned with the new learning goals. Drs. Jenny Knight, Michelle Smith, Bill Wood, Jennifer Martin, Nancy Guild and Quentin Vicens helped to rewrite the questions that are in the current Intro assessment.

This fall the same assessment was given to students in MCDB 1150 (both the large and small classes). Instructors are currently evaluating post assessment scores on this assessment for both classes.

c. Assessing the effectiveness of optional peer-led study groups

During the fall 2007 semester, Intro students were given the opportunity to join voluntary study groups. The goal of this study was to measure whether study groups helped students perform better in the course. In addition, we planned to compare the two kinds of study groups offered, as their approach was different. There were a total of six study groups: 4 groups were led by Learning Assistants, and 2 groups were led by a single TA (recent MCDB graduate). The TA-led study groups, (15 students total) met once a week to discuss and review difficult concepts and correct previously known misconceptions. The LA-led study groups, (13 students per group) met once a week, but worked primarily on their homework assignments in a smaller group of 3-4 students. They also worked on several hands-on models and were introduced to concept mapping as a learning tool. An additional group of students (25) served as a control for this study: these were students who wanted to join the study groups, but were turned away due to lack of resources.

Jia Shi worked closely with the TA and LAs to prepare them for the upcoming study group activities, whether they were hands-on activities, homework material content, or difficult concepts/misconceptions. Jia Shi assigned each LA to develop a course project based on working with 3D molecular models. LAs were very motivated for these projects and they had opportunities to present their work in the weekly meeting with Jia Shi. The practice at these meetings helped the LAs communicate with students effectively during the study group times.

The majority of the students who participated in the study groups rated their experience as “highly satisfied” ; they also gave high ratings to their TA/LAs. In addition the course performance of the study group students was better than the control group of students. We are continuing to analyze this data, and prepare it for publication.

d. Understanding student learning and thinking

Several conceptual assignments were added to the course this year that will provide Jia Shi an opportunity to analyze how students are thinking and learning in this course. These assignments were: conceptual homework assignments, a research paper on a disease of the student’s choice, in-class clicker questions, and in-class conceptual pop quizzes.

e. Assessing student attitudes towards the course

We designed attitude surveys that were given at the mid-point of the semester and the end of the course. At the mid-point of the semester, students rated clicker questions and homework assignments helpful for their learning. On the other hand, students indicated that the in-class hands-on activities were not very helpful. We have just started to look at the data from the end of the semester, but preliminary evidence suggests that students would have liked the hands-on activities better if they were more-structured.

f. Developing resources for faculty

Jia Shi will write a summary of the use of all materials for this course. This document and all the materials developed for the Intro course will be available to all future Intro instructors.

Jia Shi is also in the process of helping evaluating the two archive systems (Brain Cookies and the archive system developed at UBC). The selected archive system will serve as a repository for organizing and retrieving all course materials.

## 2. MCDB 2150

Introduction to Genetics follows MCDB1150 and is offered every fall and spring. The typical enrollment is approximately 150 students in the fall and approximately 400 students in the spring. Last spring Dr. Mark Winey taught the 400-student course and Dr. Sylvia Fromherz taught an additional small Baker section of the course. Both Mark and Sylvia had taught this course before. This fall Dr. Ken Krauter taught MCDB2150 for the first time. Dr. Michelle Smith (STF) started working with this course in January 2007.

a. Development of course learning goals

During the spring 2007 semester, Michelle worked with the instructors to develop a common set of learning goals for the genetics course. These goals were initially developed by collecting learning goals that Sylvia had started to write, syllabus topics from Mark, and exams and study guides from both instructors. Michelle's learning goal drafts were discussed and edited by Drs. Jia Shi and Bill Wood, and then presented back to the instructors. After several iterations, a common set of course and topic learning goals were agreed upon for MCDB2150. Ken Krauter taught the Principles of Genetics course for the first time this fall and used these learning goals to plan his course.

b. Development of a pre/post genetics assessment to measure student learning

Last January, Mark Winey, Sylvia Fromherz, and Michelle Smith combined previously written clicker and homework questions to develop a first draft of a pre/post assessment for genetics course. The pre/post assessment was used in the spring courses, and revealed some student misunderstandings, but the assessment still needed considerable modification. The assessment was almost completely re-written over the next semester, including removing or rewording questions so that they did not include scientific jargon, removing questions that were too easy (question on which the average pre-assessment score was >90%), and finding better distracters for incorrect answers (the new distracters were primarily taken from student's incorrect answers to open ended questions) In addition, once the course learning goals were agreed upon, the genetics instructors wanted the assessment questions to specifically address the course learning goals. To help validate the assessment, Michelle Smith interviewed 22 students that earned A's-D's in previous genetic courses. Drs. Jenny Knight and Bill Wood helped to review transcripts of all of the interviews and rewrite the questions that are in the current genetics assessment.

This fall the assessment was given to students in MCDB2150 and MCDB 1041 (the non-majors genetics course at CU), and to students in genetics courses at Bridgewater College in Virginia and Georgetown University in Washington, D.C. Despite differences in student prerequisites and institutional entrance requirements, the assessment revealed that students at all three institutions have common widespread misunderstandings at the beginning of genetics courses. Instructors at all three institutions are currently evaluating post assessment scores on this same test. In the future, we will all be working together to share teaching tools that are effective at addressing widespread student misunderstandings. In addition, the instructors at Bridgewater College and Georgetown University are planning to give the pre/post assessment to their courses again next year, as will the instructors at CU.

c. Assessing the value of group interaction in the genetics course

During the spring 2007 semester, genetics students were given the opportunity to join voluntary study groups. Thirty-eight students met weekly to work on their homework assignments together. Three undergraduate learning assistants (LAs) led these study sessions. Michelle Smith worked with the LAs to prepare them for the homework material content and to help them develop a Socratic questioning method when interacting with the students. The majority of the students who participated in the study groups rated them as "highly useful." In addition the course performance of the study group students was significantly better than a randomly selected group of

students that had a similar pre-assessment score average but did not participate in the study groups. These study groups will be offered again during the spring 2008 semester. We have hired 5 LAs to run the sessions and we will offer places for up to 125 students.

Ken Krauter and Michelle Smith attended the National Academies Summer Institute for Undergraduate Education in Biology in July 2007 and were exposed to information on various teaching styles. As a result, Michelle's research project for the semester involved developing group tutorial activities and highly interactive lectures (with many clicker questions and general questions posed to the students) for the MCDB2150 genetics course at CU and studying these two teaching styles in more detail. Jenny Knight, who has taught the non-majors genetics course for several years and has developed weekly group tutorial activities for her class, edited the activities for MCDB2150 on a weekly basis.

To facilitate this study, on Mondays and Wednesdays during the fall 2007 semester the 140-person class attended lectures that included clicker questions in a traditional lecture hall. On Fridays the class was split into two equal-sized groups and the students attended class in a new MCDB classroom designed for interactive teaching (students are seated at round tables rather than lecture-hall style seating). The content was the same for the two groups, but the presentation style differed as follows:

**Section 1:** Students listened to lectures with approximately 8 clicker questions and 2 general questions per lecture for the first half of the course. For the second half of the course, the students learned the material through group tutorial activities. LAs, TAs, and course instructors were available to facilitate student learning during the group tutorial activities.

**Section 2:** Students learned the material through group tutorial activities for the first half of the course. For the second half of the course, the students listened to lectures with approximately 8 clicker questions and 2 general questions per lecture.

Student learning in these two sections was monitored in a number of ways. At the end of each Friday session, students took a clicker quiz. The clicker quiz questions asked students to apply what they learned that day to a new situation. Students performance was also monitored on homework problems and exams. The only significant difference in student performance between the two groups was detected during the clicker quiz at the end of each session. During the first half of the course, students in Section 1 (interactive lecture first) scored significantly better on the clicker quizzes than students in Section 2 (tutorial activities first). However during the second half of the course, students in Section 1 (tutorial activities second) and students in Section 2 (interactive lecture second) have clicker quiz scores that are significantly equivalent. During the spring 2008 semester we will be contacting students from the fall MCDB2150 course and asking them to take a quiz that will measure their retention of specific genetics concepts. We plan to use this data to compare retention differences in Section 1 and Section 2.

d. Assessing student attitudes towards the course

We have also designed attitude surveys that were given at the mid-point of the semester and the end of the course. At the mid-point of the semester, we detected some significant differences in student attitudes between the two sections. Namely,



the students in Section 1 (interactive lecture first) rated their section as more helpful in assisting them with learning the course material than students in Section 2 (group tutorial activities first). We have just started to look at the data from the end of the semester, but preliminary evidence suggests that students from both sections are now rating the group tutorial activities as valuable. We are finishing the data analysis on this project and plan to use the information to drive curriculum change in the MCDB department and will submit our findings as a research paper in the upcoming year.

e. Developing resources for the faculty

Michelle Smith has been working with Mark Winey, Ken Krauter, and will be working with Dr. Tin Tin Su in the upcoming Spring 2008 semester to develop a genetics multiple-choice question bank that can be used for homework questions and as clicker questions. These questions are aimed at targeting widespread student misunderstandings and focus on the analysis of published data. The question bank will be available to all future genetics instructors. In addition, Michelle will be summarizing and cataloguing all of the course materials that have been developed over the past year, as well as describing how LAs were used, for future faculty use.

3. MCDB 1041

The MCDB1041 non-majors Genetics course has been taught each fall for the past 7 years by Dr. Jenny Knight. The course has approximately 90 students per semester. Over the years, Jenny has developed learning goals, group activities for the class, and a bank of clicker questions. The class meets together on Mondays and Wednesdays, and separates into 4 LA-led groups to do interactive group work (this format has been in place for 3 years) on Fridays. Jenny has informally measured student attitudes towards science, and towards group work over the past few years, as well as using a first draft assessment tool to measure learning gains. This semester, Jenny administered the newly developed genetics assessment described above, both pre and post, to the non majors class. The content of the two courses overlapped enough that 19 of the 25 questions addressed learning goals in the non-majors class. In addition, Jenny and Michelle developed some activities together for the two courses, so that the same areas of students misunderstanding could be approached and evaluated in both courses. The persistence of student misunderstanding was addressed on several topics by asking quiz questions at the end of group activities, and then asking similar questions on these topics on exams. These topics will be assessed again on the post assessment. We also measured student attitudes about group work and other course components using the same questions as were used in MCDB 2150. We plan to use the data collected to write a paper that compares how non-majors and majors differ in their approach to learning genetics, how persistent they are in their misunderstanding, and how their attitudes about science and group work change over the semester. In addition, the data will help Jenny make further improvements to how the course is taught in future semesters.

4. MCDB 3500

After the MCDB2150 course students typically take MCDB3500 Molecular Biology. During the fall 2007 semester Michelle Smith began working with Dr. Ravinder Singh on this course. Course and topic learning goals have been drafted for this course and an assessment tool based on the learning goals was given. In addition Michelle has worked

with Ravinder to help him develop some interactive exercises for his course. All of these activities will continue in the upcoming year.

#### 5. Development of a pre/post assessment of student attitude about biology

A pre/post assessment of student attitude in Physics called the CLASS has been used to compare novice and expert thinking among physics students. Questions from the physics CLASS were modified for biology, however students and experts (Biology Ph.D.'s) had not validated the questions. This year several MCDB faculty members met to discuss rewording the questions and Michelle Smith and Kate Semsar (physiology STF) interviewed 15 students about the questions. The questions were also validated by over 80 biology experts, which are Ph.D.s from a variety of biology subdisciplines (ecology, physiology, and molecular biology). Approximately 2,000 CU biology students in EBIO 1210, MCDB 1041, 1150, and 2150, and IPHY 3410 took the survey this fall and we currently analyzing the data. Preliminary data suggests that students shift towards more novice-like thinking during their introductory biology courses. We are using the data to help faculty integrate more expert-like thinking information into their courses.

### **C. Departmental faculty development and involvement in SEI efforts.**

The number of faculty working with the SEI staff has increased in the past year. Corrie Detweiler and Ravinder Singh have both been involved in the working group meetings, as well as getting occasional help from both STFs as they work on modifying their upper division courses (Immunology and Molecular Biology, respectively). All faculty working with the STFs have come to at least one working group meeting over the past year, and have been interested and willing to participate.

Bill Wood offered the Teaching and Learning Seminar again this fall (MCDB 6440), and this seminar will be offered again by Bill and Jenny in Spring '08.

Jia Shi and Michelle Smith reported on their work last summer during the summer departmental seminar series. In addition, Jenny, Jia and Michelle all attended the fall departmental retreat, giving a talk and posters on the SEI work.

### **D. Goals for 2008**

1. General:
  - a. The SEI group will be working on writing and publishing at least three papers in the next year on each of the three studies described above.
  - b. The working group will continue to meet, preferably every 2 weeks.
  - c. The STFs will archive their work on MCDB 1150 and 2150 for use by future faculty. In addition, they will develop explicit training procedures for LA use, so that the faculty can gradually take over this responsibility. Although the STFs will continue to be associated with these courses in 2008, their role will be more advisory, as they shift their focus to the next series of courses.
  - d. Contribute questions to clicker database, organized by topic
  - e. Begin work on simulation projects, if resources and time permit.
2. Assignments for Jia Shi in 2008

- a. Data analysis for 2007 work, MCDB 1150
  - b. Begin work on MCDB 3120, Cell Biology
  - c. Spring 08—attend class, take observations of current course structure and content, develop learning goals with Dr. Bob Poyton.
  - d. Summer—develop assessment tool, clicker questions, other course materials for faculty use
  - e. Fall 08—work with faculty assigned to 3120 (not yet clear who is teaching the course) to implement modest changes, use assessment tool for 1<sup>st</sup> time.
  - f. Serve an advisory role in Fall 08 for Intro MCDB 1150
3. Assignments for Michelle Smith in 2008
- a. Data analysis for 2007 work, MCDB 2150
  - b. Work with Tin Tin Su on MCDB 2150, Spring 08
  - c. Optional study groups run by LAs will again be provided to the students (5 LAs have been hired for Spring).
  - d. Research project on clicker question use: Does student discussion of answers to conceptually difficult clicker questions improve their ability to answer future questions individually?
  - e. Provide limited advice and support to Dr. Jens Lyke-Anderson, who will be teaching Molecular Biology 3500 (Spring 08).
  - f. Beginning in the Summer/Fall, Michelle will shift to working primarily on Molecular Biology 3500 (Dr. Singh).
  - g. Revise and interview on assessment tool for Molecular Biology
  - h. Continue developing learning goals and interactive tools for addressing those course goals

## VIII. SEI in Physics

### A. Departmental structure of the SEI program

The Physics proposal to the Science Education Initiative (SEI) in 2005 was revised and resubmitted in 2007, and it was funded by SEI in Spring 2007. The intent of the proposal is to try to extend physics education research-based teaching methods into upper division physics curriculum for majors. The key provisions of the proposal were:

- Emphasis will be placed on determining the learning goals for existing courses. Learning goals are a prerequisite for course and teaching technique evaluation.
- Emphasis will be placed on developing course evaluation tools for existing courses.
- Funding for any specific course project, whether for pure evaluation or for course modification, will be initiated by a faculty proposal.
- The Department of Physics will act as a repository for syllabi, course materials, associated evaluation tools, and the results of course and student learning evaluations.

- The Department of Physics will participate in the creation and distribution of technical and attitude surveys to our students, to attempt to evaluate the value of our curriculum and teaching techniques.
- Courses that are early in the curriculum and/or courses that enroll large numbers of students should receive attention first.

In Spring 2007 the department initiated a search for a Senior Teaching Fellow to coordinate course reforms in Electricity and Magnetism (PHYS 3310). Dr. Stephanie Chasteen was chosen and began work in the department on September 1, 2007. Paul Beale was selected by the Chair to serve as the faculty liaison to the SEI.

Prior to the commencement of the SEI in Physics, faculty members were polled on their level of interest and time commitment to the SEI program. About half the faculty responded, and most indicated a willingness to use materials created by the SEI and/or provide feedback on the work of the SEI (such as learning goals and a post-test assessment tool). Out of that survey a small working group emerged, which includes Kathy Perkins, Paul Beale, Noah Finkelstein, Tobin Munsat, Oliver deWolfe, Tom deGrand, Anna Hasenfratz, Michael Dubson, Steve Pollock and Shanta De Alwis. This core group meets twice a month to discuss issues pertinent to the reform of PHYS 3310 (Electricity & Magnetism 1), and the feedback of this group of faculty has provided crucial direction for the Science Teaching Fellow. In addition, an undergraduate Noyce Fellow, Ward Handley, has assisted with observation of the course and development of concept questions.

## **B. Course-related efforts**

Electricity & Magnetism 1, PHYS 3310, is required for completion of the BA in Physics, Astrophysics and the BS in Engineering Physics – about 80% of the course is populated by these majors. The remaining students are comprised of mathematics majors (11%), other natural science majors (4%), and other miscellaneous and undeclared majors (7%). Typically, this course is taken by juniors and seniors, and the enrollment is 30-50 students. Several faculty have taught this course – in the past five years. Recent instructors have been Anna Hasenfratz (taught twice), John Bohn, Uriel Nauenberg, Mihail Horanyi, and Charles Rogers. The current instructor is Scott Parker. In about half the cases, the same instructor teaches PHYS 3310 and the second semester course, PHYS 3320.

In Spring 2008 Steven Pollock will teach the course, using the reforms being developed this semester. Concurrently, Michael Dubson will teach and reform Quantum Mechanics and Atomic Physics 1 (PHYS 3220). In Fall 2008 Michael Dubson and Steven Pollock will switch. Michael Dubson will co-teach the reformed PHYS 3310 with Ed Kinney and Steve Pollock will co-teach the reformed PHYS 3220 with Oliver DeWolfe. In Spring 2009 Ed Kinney will teach PHYS 3310 and Oliver DeWolfe will teach PHYS 3220. Those instructors may choose to accept the developed course reforms as they deem appropriate.

Ongoing activities include:

1. Developing learning goals.

Working in close conjunction with the faculty working group and input from individual faculty interviews, STF Stephanie Chasteen has drafted course-scale and lecture-scale learning goals for PHYS 3310. These goals have so far met with general agreement, and the course-scale goals are in the process of being finalized.

## 2. Interviews with faculty.

Stephanie Chasteen has interviewed seven faculty members who have previously taught PHYS 3310 or the second-semester course PHYS 3320, and has spoken extensively with the current instructor. Key issues raised by faculty are importance of the vector calculus and differential equations techniques learned in the course, as well as a high level of mathematical sophistication and physical insight (largely through mathematics) required of students in the course. Several have expressed a concern that there is not a systematic effort to assign the same instructor to the first and second semesters of the course, which they believe is a detriment to the students. The content of the course itself is fairly generally accepted, though individual instructors vary on their explicit coverage of topics in vector calculus (a prerequisite) and whether they cover topics in electrodynamics at the end of the course.

## 3. Developing an assessment instrument for measuring student learning

Stephanie Chasteen has developed a post-test assessment tool based on learning goals, and has performed preliminary validation of the instrument through interviews with experts (ie., faculty), and students. A total of 5 students were videotaped while they took the test and explained their reasoning out loud, and a total of 27 students took the test as an in-class diagnostic exam. Results will be available in January 2008.

This instrument will not serve as a pre-test, since most students have not previously been exposed to much of the content of the course. Instead, Steven Pollock is developing a pre-test to assess students level of comfort with techniques in vector calculus and other mathematical prerequisites.

The Basic Electricity and Magnetism Assessment (BEMA) has been given to students in the course, and will continue to be given in future semesters. This tool assesses student understanding of concepts in electricity and magnetism at the freshman/sophomore level, and has been given to students in 3310 over the past several years.

Students in PHYS 3310 were also asked to complete an attitudinal survey regarding the course, including questions about their homework and study habits, and whether they thought the content in the course was relevant and interesting.

The results from these tests (post-test, BEMA, and attitudinal survey) are being analyzed by the team.

## 4. Understanding student learning and thinking

To develop an understanding of student thinking and difficulties in the course, Stephanie Chasteen observes weekly lecture and recitation and, along with Ward Handley, runs a weekly homework help session. She also reads student homework and exams, and solicits observations from the TAs in the course. All these observations are compiled into chapter-by-chapter documentation on student learning in the course.

## 5. Developing/using/refining new teaching techniques

Stephanie Chasteen, Ward Handley, and Steven Pollock meet weekly to discuss the course and to develop concept and clicker questions. Stephanie Chasteen has also been gathering information from other universities and various alternative teaching techniques, such as alternative homework assignments and use of group work in upper division

courses. In Spring 08, Dr. Pollock and Dr. Chasteen will likely be assisted by another undergraduate, Darren Tarshis, who will be serving as a Learning Assistant for the course. Darren will develop questions and class activities and assess their effectiveness.

#### 6. Developing resources for faculty

All materials generated for PHYS 3310 will be available to future faculty who teach the course. One resource many have requested is a bank of homework and exam problems that they can draw upon. These questions will be chosen and developed to align with the learning goals for the course, allowing faculty to provide students with assignments that may develop a wider variety of student skills than those that a single faculty can easily create. Similarly, the concept/clicker questions developed for the course will be provided as a ready-to-use resource for faculty.

### **C. Departmental faculty development and involvement in SEI efforts.**

The faculty working group comprises the core group of faculty involved in SEI efforts, and other faculty are aware of our efforts through water-cooler conversations and more formal individual faculty interviews. Through our conversations, several issues have been raised (i.e., a desire to have the same faculty member teach two semesters of the junior-level courses, and a concern about the preparation that students are receiving in the math courses), which suggest that the general faculty may be interested in infrequent meetings on issues of more general interest.

### **D. Goals for 2008**

General:

- Facilitate general discussions for physics faculty regarding teaching issues (e.g., instructor continuity across two-semester courses)
- Encourage conversation between physics and math faculty regarding preparation of students for upper division physics courses

Goals for work on 3310:

- Code and analyze pre- and post-assessment tools, including student and faculty interviews
- Obtain wide faculty agreement on learning goals at course-scale and chapter-level
- Implement reforms beginning in Spring 2008:
  - Create “tutorials” for junior-level electricity and magnetism (such as working concept-rich problems)
  - Design and teach interactive problem-solving recitation sessions
  - Assign homework assignments that go beyond standard calculations and address the learning goals
  - Write and implement clicker questions
  - Change lecture techniques as appropriate
- Compare learning gains between traditional and reformed course
- Compile bank of homework, exam, and clicker questions

- Investigate key areas of student difficulty through student interviews.
- Identify key questions, which will lead to systematic research studies within the course. One topic of interest is the way in which mathematics are used to gain insight into the physical system. The physics in this course is often of a level of sophistication such that the answer can no longer be guessed in advance, and the mathematics becomes a tool for understanding physical systems in which insight is no longer sufficient. The achievement of a certain degree of mathematical fluency, in which the equations hold meaning about the physical world, is a key skill gained by the successful student in this course.