STEM GATEWAY

Gateway Science and Math Course
Reform Program – Proposal
2013-2014
Due: March 18, 2013

Basic Course Information

Course number (including department/program prefix): CHEM 121 at UNM, 1710 at CNM

Course name: General Chemistry I

If companion laboratory or recitation/problem solving sessions have a separate course number/title, then please list these separately in this space:

CHEM 123L: General Chemistry I Lab
CHEM 1792: General Chemistry I Lab

Typical number of sections taught during fall, spring, and summer semesters (listing lab and recitation/problem solving sessions separately from the lecture):

UNM
Fall: 4 sections, one of which is BA/MD section
Spring: 3 sections, one of which is a online course
Summer: 1 section
CNM
Fall: 12 sections
Spring: 12 sections
Summer: 7 sections

Short description of how course serves as a gateway to courses in the department and to other majors:

General Chemistry I (CHEM 121) fulfills the New Mexico Lower Division General Education Common Core Curriculum Area III requirement and is also a gateway course for majors in science and engineering, providing an introduction to atomic structures, stoichiometry, gases, thermochemistry, chemical bonding, molecular geometry, and periodicity. CHEM 121 is required by 5 engineering departments and by all A&S science degrees (Biology, biochemistry, Chemistry, Earth and Planetary Sciences, Physics), and enrolls about 1300 students at UNM and 750 at CNM per year. As such it is a keystone both for recruiting students into the STEM disciplines and for providing a background for more advanced work. About half of all students taking 121 are declared as Biology or pre-health science majors and a quarter are engineering majors. It is a prerequisite for key courses such as CHEM 122 and Bio 201, which are also gateway courses.

Perceptions of reasons for low student achievement of passing grades, rigorous course outcomes, or both:

CHEM 121 has made the UNM 'killer course' list with the percentage of students not succeeding and hence unable to progress in their STEM field ranging between 20 and 50%. Students in CHEM 121 usually come to classes without clear motivation and are also less familiar with the college setting, putting them at a disadvantage in terms of metacognitive skills. CHEM 121 is usually taught in large sections (250-300 students) using a traditional lecture format. The large enrollment lecture environment often results in, at best, knowledge transfer and passive learning. Students do not have the the time or opportunity in class to construct their own concepts and ask questions. Too often, students are alone at home when they are required to apply the most challenging material in the course. In addition, research suggests that low income and first-generation college students (~45% of UNM's student population) may be disproportionately disadvantaged in the lecture dominated environment. Students struggle with the pace of the course, the sheer volume of coverage, the mathematics needed to apply the material, the impersonal nature of the large lecture hall with little interaction and the often very abstract nature of the material learned without explicit context. Faculty often perceive that students are less prepared for class than desired, that there is a tendency to rote-memorize course materials, and a real difficulty with multistep problem solving.

Course reform team members

Each team should consist of 3-4 UNM faculty members who regularly teach the course. Including a commonly employed part-time instructor is desirable. Each team must also include an instructor of this same course at CNM. If you do not know an appropriate CNM colleague, please contact Gary Smith at OSET for guidance (277-2297; gsmith@unm.edu). A graduate assistant from the UNM department will also be hired to assist the team. Each team member must commit to participating in the events and processes listed on the first page of this document.

UNM Faculty Member; Name Dr. Kuangchiu Joseph Ho

Rank/Position Director of Chemical Education, Lecturer III, Research Professor

Number of years teaching this course 10

Typical number of sections of this course taught each year 3 in the past, coordinate all CHEM 123L

UNM Faculty Member; Name Dr. David J. Keller

Rank/Position Associate Professor

Number of years teaching this course 3

Typical number of sections of this course taught each year 2 in the past, 0 last 3 years

UNM Faculty Member; Name Dr. Sushilla Knottenbelt

Rank/Position Visiting Assistant Professor

Number of years teaching this course 3

Typical number of sections of this course taught each year 2

UNM Faculty Member; Name Dr. Shaorong Yang

Rank/Position UNM part-time instructor, Full-time faculty at CNM

Number of years teaching this course 4

Typical number of sections of this course taught each year 2

CNM Faculty Member; Name Ms. Clarissa Sorensen-Unruh

Rank/Position UNM Part-time instructor, Full-time Faculty at CNM

Number of years teaching this course 10

Typical number of sections of this course taught each year 3-5

A. Student learning outcomes

1. Relate the development of essential chemical theories to the application of the scientific method. (Related to HED Core Competencies Area III no. 1)
2. Use dimensional analysis, the SI system of units and appropriate significant figures to express quantities, convert units and perform quantitative calculations in science. (Related to HED Core Competencies Area III no. 2 and 5)
3. Diagram the structure of the atom in terms of its subatomic particles. Justify the existence and nature of the subatomic particles and the scale of the nucleus using appropriate experiments from scientific history. (Related to HED Core Competencies Area III no. 1 and 2)
4. Use the IUPAC system of nomenclature and knowledge of reaction types to describe chemical changes, predict products and represent the process as a balanced equation. (Related to HED Core Competencies Area III no. 4)
5. Apply the mole concept to amounts on a macroscopic and a microscopic level and use this to perform stoichiometric calculations including for reactions in solution, gases and thermochemistry. (Related to HED Core Competencies Area III no. 2 and 4)
6. Apply the gas laws and kinetic molecular theory to relate atomic level behavior to macroscopic properties. (Related to HED Core Competencies Area III no. 2 and 4)
7. Describe the energy conversions that occur in chemical reactions, relating heat of reaction to thermodynamic properties such as enthalpy and internal energy; calculate and describe how to measure energy changes in reaction. (Related to HED Core Competencies Area III no. 4 and 5)
8. Explain the experimental basis for the dual nature of matter and energy (electromagnetic radiation) and apply basic quantum mechanics to describe the electronic structure of the atom. (Related to HED Core Competencies Area III no. 4)
9. Describe the ways in which atoms combine to form molecules (ionic and covalent) using different bonding models. Apply knowledge of electronic structure to determine molecular structure, geometry and hybridization. (Related to HED Core Competencies Area III no. 4)
10. Analyze how periodic properties (valence, electronegativity, etc.) and reactivity of elements result from electron configurations of atoms. (Related to HED Core Competencies Area III no. 4)
11. Solve problems of chemical relevance with multiple layers of data analysis. (Related to HED Core Competencies Area III no. 4 and Area II no. 2)

B. Proposed Elements of the Reformed Course

General Chemistry I (CHEM 121) is a gateway course for majors in science and engineering. CHEM 121 shares the same learning difficulties as CHEM 122, resulting in similarly high W/D/F rates, and preventing many students from continuing with their chosen STEM major. We submitted a course redesign proposal for CHEM 122 last Spring, and intend to use our experience from a successful redesign to return to CHEM 121. In CHEM 121, we face a problem that is less apparent in CHEM 122, motivation for learning chemistry. Unlike CHEM 122 students who have oftentimes made their decision as to their field of study, many CHEM 121 students are not sure why they need to learn chemistry. The CHEM 121 students are also less familiar with the college setting, putting them at a disadvantage in terms of metacognitive skills. We propose to improve student motivation, learning and retention in CHEM 121 by a course re-design emphasizing active learning, interdisciplinary exercises and multi-component assessment. Success will be gauged by a reduction in the W/D/F rate, improved student learning as measured by internal assessments, and measures of student satisfaction. Themes of this re-design will be

1. Revising learning outcomes to coordinate with skills and competencies needed in STEM majors requiring CHEM 121.
2. Refining active-learning techniques to optimize learning in learner-centered environments.
3. Developing interdisciplinary exercises pitched at higher cognitive levels to provide a strong basis for student engagement and deeper learning.
4. Assessing student, class and re-design performance via multi-component measures of student learning and student opinions on how the class structure facilitates their own learning.

Of the 1300 students who take CHEM 121 each year at UNM, less than 5% go on to become chemistry majors; of the remaining 95%, nearly half become biology and pre-health science majors, while about a quarter become engineering majors. Incorporating the needs and expectations of these departments into the course learning outcomes is essential if CHEM 121 is to remain relevant as a gateway STEM course. At the same time, outcomes must be related to subsequent chemistry courses (CHEM 122/124L) to keep students up to date in chemistry and prepare them for advanced topics.

Extensive research points to improved student learning when using active learning pedagogies in the classroom. A significant study suggests that using these methodologies in the classroom can make more difference to student learning than the choice of instructor to teach them. In order to make time in the classroom to engage in such activities, we plan to use an "inverted classroom" approach, where the acquisition of the basic facts and concepts becomes the responsibility of the students before class, via structured reading assignments or online resources. Class time will then be focused on more difficult concepts, applications and synthesis in which the instructor and peer-learning facilitators help students engage with exercises designed to explore the outcomes. Clicker questions will be used to assess learning in these exercises, but also as a tool to promote student participation and engagement.

Interdisciplinary exercises can motivate students by the area of application and the level of conceptual integration, and engage higher-order reasoning skills. We plan to develop examples in engineering, health sciences and geochemistry since a major goal will be to show students how CHEM 121 principles can be applied in different STEM fields. Exercises will combine pre-class reading with in-class problem solving and optional post-class follow-up reading to see how the problem is solved in the "real world" of application. In addition, these exercises will target known misconceptions and student difficulties and will aim for Bloom's taxonomy levels above simple knowledge and comprehension to application and above. Use of open source educational resources including the Journal of Chemical Education will allow the exercises to be textbook independent. Peer learning facilitators will be employed in larger sections to ensure that student groups remain "on track" during in-class exercises.

At least one section per semester of CHEM 121 is currently taught with pre-class quizzes and active lecture, and we have seen improvement in some semesters in the DFW rate. However, the class still makes the 'killer course' list, and we believe that we can improve the outcomes of students taking the course with our experience from our CHEM 122 redesign by developing better engaging exercises, with better linked formative assessment. We are interested in the conditions that optimize small-group learning in the classroom. One thing we learned from CHEM 122 redesign is the importance of faculty development for the reform approach. Faculty who will teach the new course should have opportunities to practice the reform approach during the development. We propose to use training videos and practice the course activities with graduate assistant, PLF and SI leaders during the weekly meetings and the faculty pre-training. We plan to structure the redesign so that materials will be easy to use for instructors of all sections, and importantly, those not involved in the initial redesign.

<u>Timetable for redesign:</u>

Summer 2013: The redesign plan is finalized with OSET guidance by June 1st. The team will collaborate to develop materials for implementation, starting Fall 2013. The concept tests to use as pre- and post-course assessment will be revised before the Fall semester starts. By the start of Fall 2013 we will have:

1. Established course learning outcomes that align with HED competencies and STEM major requirements.
2. Developed structured pre-class reading assignments and formative assessments to enable students and instructors to monitor acquisition of basic facts and concepts before class.
3. Created in-class, interdisciplinary exercises and questions which require higher-order thinking with optional follow-up references. These will be combined with clicker questions that test these higher levels of thinking for assessment in the large classes.
4. Created a detailed multicomponent assessment plan for the initial implementation.
5. Developed subject-specific training materials for learning facilitators (TAs, SI and PLFs in the classroom)

Fall 2013: At UNM, there will be 3 sections of the test group using the reform approach and three sections of control group using the teacher-centered approach. The test group consists of a BA/MD section (Knottenbelt) using collaborative classroom (DSH224), one section using the large studio collaborative classroom (Knottenbelt), and one section uses a traditional lecture room (Sorensen-Unruh). The 3 sections of control group will use traditional lecture rooms, and a pre- and post-concept test administered to ALL students taking CHEM 121. At CNM, one section of CHEM 1710 (Sorensen-Unruh) will be taught as a hybrid class using the initial redesign plan. Assessment data will be collected during the semester (see detailed assessment plan following) and evaluated over Winter Break to inform the Spring implementation and assessment plan. We plan to evaluate the data incrementally over the semester, and meet before 1/6/2014 to make recommendations for adaptations in the Spring.

Spring 2014: 3 sections of CHEM 121 at UNM, including one using the studio classroom will apply the improved redesign plan taught by at least 2 different instructors (Yang and Sorensen-Unruh) and 2 at CNM (Sorensen-Unruh). Assessment data will be collected. We want to continue testing the small-group learning using the large studio classroom (120 students) as one of the three sections of CHEM 121 offered by a different instructor.

Summer 2013: 1 section of CHEM 121 at UNM (Yang). The course redesign team will evaluate assessment data collected over the year, and present the results and make recommendations for future implementations to the Chemistry Faculty at the annual Faculty retreat.

Fall 2013 and beyond: Assuming positive redesign results, the implementation will be extended to all sections of 121 in Fall 2014 and Spring 2015. To enable longer term assessment of the impact of the redesign, the Chair of the Department of Chemistry and Chemical Biology at UNM has committed to providing 1 month of compensation for Drs Ho and Knottenbelt to continue the analysis of assessment data in the summers of 2015 and 2016.

<u>Additional resources:</u>

In order to enable active learning in the classroom, we request at least 2 years of support for Peer-Learning-Facilitators in all CHEM 121 classes at UNM that implement the course redesign. We request 1 PLF for every 50 students above a base of 50 students. We anticipate needing 14 PLFs for Fall 2013 and 6 PLFs for Spring 2014.

<u>Personnel and Experience:</u>

As Director of Chemical Education, Dr. Ho provides the leadership and continuity needed for an ambitious redesign. He has twenty two years of teaching experience in undergraduate chemistry courses and labs. He coordinates the labs associated with CHEM 121 and CHEM 122 and has recently redesigned them both to replace 'cookbook' labs with ones fostering the scientific method. He is currently developing the Chemical Concept Inventory that we intend to use for pre- and post- assessment and has implemented active learning techniques in his CHEM 122 summer section since 2010.

Dr Knottenbelt has implemented much of the methodology proposed herein in her Chem 121 sections in Fall 2010 and Spring 2010 and 2011, with the support of OSET and the Walmart Foundation. The redesigned course has achieved increased student retention and learning, as well as very positive student evaluations.   She is currently using collaborative learning techniques to teach a section of CHEM 122 targeted at pre-health sciences in the new seat collaborative classroom (DSH224).

Dr Keller has previously taught General Chemistry I and II and honor's general chemistry I and II. He has taught both the undergraduate and graduate chemistry courses. His experience teaching students in different levels of chemical education will help the team develop course materials more connected to the practical use in the upper division courses.

Dr Yang started teaching during his graduate years at UNM and has been a part-time lecturer at CNM for two years and at UNM since Summer 2011. He is considered one of our regular part-time instructors. He is also now full-time faculty at CNM, and works with Ms Sorensen-Unruh to bridge between UNM and CNM. He strives to improve student learning by encouraging them taking a leading role and employing creative instructional techniques enhanced by technology. He is an active member in our General Chemistry committee, contributing much to our discussions.

Ms Sorensen-Unruh is full-time faculty at CNM teaching the full range of chemistry classes offered there. She teaches these classes in multiple environments, including interactive lecture (with group work), hybrid and blended. She is currently teaching a section of Chem 121 at UNM, transferring the structure developed by Dr Knottenbelt, in order to strengthen ties with UNM colleagues. She has always engaged her students in active learning, and has added the on-time assessment (pre-class reading quizzes, muddy points, and clickers) in Chem 121 and all her classes at CNM.

C. Assessment Plan

We are looking for the answers of the following questions in our assessment plan:

1. Do active learning strategies of this reformed approach adequately prepare students to be successful in the next science courses?
2. Does the reformed approach benefit a special group of students?
3. Can peer-led group learning be scaled up in the large studio classrooms?

For question 1, we will have a short-term and a long-term assessment plan. Since the two large groups of students taking CHEM 121 are biology and engineering majors, we will focus on the preparedness of students for Biology 201 and CHEM 122. Both courses have CHEM 121 as the pre-requisite. In the short-term plan, we will include discipline-oriented questions in the worksheets to assess students' ability to apply the chemistry principles and concepts in the related topics of their next courses. We will work with instructors in biology in the design of these questions. In the long-term plan, we will track our students' performance in their next science course that requires CHEM 121. We will use the course grade and drop-out rate as the measures. We will also use surveys for non-cognitive measures. The short term assessments will be collected by course instructors and analyzed by Ho each semester. The long-term assessments will be collected and analyzed by Ho in the summer of 2014 and 2015.

For question 2, we are interested in finding the learning progress of different grade levels of students reacting to the active learning strategies. Previously in the reform project of CHEM 122, we found the learning from all grades, A, B, and C, is equal in the reformed section , but the degree of learning was proportional to student's course grades in the teacher-centered sections. While the improvement of learning in the C group is encouraging, we'd like to know if the learning in the A group was somehow inhibited in the reformed approach. To answer this question, we will implement different levels of questions in the midterm and final exams. By analyzing students' performance of these questions between the test and control sections, we will try to draw a conclusion. This effort requires a coordination among instructors led by Knottenbelt when preparing these exams. The data will be collected by instructors and analyzed by Ho in the Fall semester of 2013.

For question 3, we will compare the performance of students in small section using DSH 224 and the performance of students in a large section using the new studio classroom, both use the active learning strategies. The performance measure will be pre- and post-test, CLASS surveys, midterm and final exams. We will also use surveys given to students, TA's, SI leaders, and PLF's. We will analyze the performance in the Fall semester of 2013 and use the results to refine our implementation of the spring semester of 2014. We will carry out the assessment for the spring semester of 2014 before we make a summary conclusion for the question.

The results of the proposed assessments will be disseminated in journal publications, regional and national conferences, and departmental faculty trainings for teaching the reform approach. We ask for funds that can pay for the supplies for the preparation of the dissemination material and expenses for attending conferences.

D. Cited References

1. Improved learning in a large enrollment physics class, Louis Deslauriers , Ellen Schelew, and Carl Wieman, *Science*, 332, 862-864 (2011)
2. Peer Instruction: Ten Years of Experience and Results Eric Mazur *Am. J. Phys.*, 69, 970-977 (2001).
3. The concept inventory is adapted from the CCI, as made available from the Journal of Chemical Education. Our 'in house' adaptations include new questions on areas of specific interest to us. We have begun the process of test validation. Link: http://www.jce.divched.org/JCEDlib/QBank/collection/CQandChP/CQs/ConceptsInventory/Concepts_Inventory.html.
4. Factors Influencing Success in Introductory College Chemistry, R. H. Tai, Philip M. Sadler, and John F. Loehr, JOURNAL OF RESEARCH IN SCIENCE TEACHING, 42, 9, PP. 987–1012 (2005)
5. Peer-Led Team Learning General Chemistry, 2nd ed, D. K. Gosser, V. S. Strozak, and M. S. Cracolice, Pearson/Prentice Hall (2006)