STEM Gateway Course Reform Team project information for STEM Gateway website.
Please complete this information and return as a Word file to Gary Smith (gsmith@unm.edu)

Course Name: General Chemistry II

Course prefix and number: CHEM 122

Course-reform team members (Name, title, institution; list team leader first and others alphabetically by last name):
Joseph Ho, Team Leader, Director of Chemical education, Research Professor, Lecture III, University of New Mexico
Stephen Cabaniss, Chair, Professor, University of New Mexico
Christopher Larsen, Graduate Assistant, University of New Mexico
Sushilla Knottenbelt, Visiting Assistant Professor, University of New Mexico
Clarissa Sorensen- Unruh, Full-time Faculty, Central New Mexico Community College
Sarah Toews Keating, Graduate Assistant, University of New Mexico
Shaorong Yang, Full-time Faculty, Central New Mexico Community College

Student learning outcomes for the course:

1. Explain the physical basis of intermolecular attractive forces; apply this knowledge qualitatively to evaluate these forces from molecular structures and to predict the relative physical properties of those molecules, including phase transitions. (HED Area III no. 2)

2. Calculate solution concentrations in various units (molarity, molality, mole fraction, % by mass, % m/v) and explain the effects of temperature, pressure and structure on solubility. (HED Area III no. 2)

3. Describe the colligative properties of solutions and explain their basis using intermolecular forces. Determine solution concentrations using colligative property values and vice versa. (HED Area III nos. 2 & 4)

4. Explain rates, rate laws, integrated rate laws, half-life and their interrelationships; determine the rate, rate law and rate constant of a reaction from concentration data and calculate concentration as a function of time and vice versa. (HED Area II nos. 1 & 2 and Area III nos. 2 & 4)

5. Explain the collision model of reaction dynamics, including activation energy and the role of catalysts and temperature; derive a rate law from a reaction mechanism and evaluate the consistency of a mechanism with a given rate law. (HED Area III nos. 2 & 4)

6. Describe the dynamic nature of chemical equilibrium and its relation to reaction rates; apply Le Chatelier's Principle to predict the effect of concentration, pressure and temperature changes on equilibrium mixtures. (HED Area III no. 2)

7. Describe the equilibrium constant K and reaction quotient Q and use them to determine the direction of reaction; calculate equilibrium constants from equilibrium concentrations and vice versa. (HED Area II no. 2 and Area III nos. 2 & 4)

8. Describe the Bronsted-Lowry and Lewis models of acid and base behavior, and the molecular basis for acid strength; be able to identify conjugate acid-base pairs and to rank related acids by strength. (HED Area III no. 2)

9. Apply equilibrium principles to aqueous solutions, including acid-base and solubility reactions; calculate pH and species concentrations in buffered and unbuffered solutions. (HED Area II no. 2 and Area III nos. 2 & 4)

10. Explain pH titration curves and speciation diagrams; be able to determine analyte pKa and concentration from the former and to determine dominant species as a function of pH from the latter. (HED Area II nos. 1 & 2 and Area III nos. 2 & 4)

11. Explain and qualitatively predict the entropy (S) of reactants and reactions; use reaction entropy, enthalpy (H), and temperature to predict Gibbs free energy (G) via $\Delta G = \Delta H - T\Delta S$; relate these to equilibrium constants and reaction spontaneity. (HED Area III nos. 2 & 4)

12. Explain oxidation and reduction processes in terms of oxidation numbers and balance redox equations in aqueous solution; evaluate the potential, free energy and equilibrium K for the overall reaction and predict the spontaneous direction. (HED Area III nos. 2 & 4)

13. Relate electrochemical cell construction to redox reaction; determine the standard and non-standard cell-potentials of galvanic cells and be able to relate current to electron transfer and reaction rates. (HED Area III nos. 2 & 4)

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

General Chemistry II (CHEM 122) 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 intermolecular interactions, chemical equilibria, reaction kinetics, thermodynamics and electrochemistry. CHEM 122 is required by 4 of 5 engineering departments and by all A&S science degrees (Biology, Chemistry, Earth and Planetary Sciences, Physics), and enrolls about 900 students at UNM and 400 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 122 are declared as Biology or pre-health science majors and a quarter are engineering majors. It is a prerequisite for key courses such as Organic Chemistry, CHEM 301 and Genetics, Bio 202, which are also gateway courses.

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

CHEM 122 has made the UNM 'killer course' list 8 out of the last 10 semesters, with the percentage of students not succeeding and hence unable to progress in their STEM field ranging between 20 and 40%. CHEM 122 is usually taught in large sections (150-300 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 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 plan (a description of the elements of the reformed course: *specific* curricular changes and/or pedagogical changes that will be designed and implemented with an explanation of how each change will address the perceived reasons for past low student achievement)

General Chemistry II (CHEM 122) is a gateway course for majors in science and engineering. For reasons outlined on the first page of this proposal, it suffers from high W/D/F rates and prevents many students from continuing with their chosen STEM major. We propose to improve student motivation, learning and retention in CHEM 122 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:

1. *Revising learning outcomes to coordinate with skills and competencies needed in STEM majors requiring CHEM 122.*
2. *Converting traditionally taught lecture courses into learner-centered environments by incorporating active learning in the classroom.*
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.*

Learning strategies planned for students:

Students will be given a detailed preparation assignment including a short multiple choice quiz and muddy point question to be completed before EACH class to enable them to acquire the basic facts and concepts necessary for each class.

In class, students will engage in a variety of active learning activities (clicker questions with peer-instruction) and application based in-class exercises. These activities will be designed to focus on the areas of student difficulty that the team has identified in the development phase of the course, and to help the students relate the concepts to real world situations. The instructor will deliver short lectures on the most difficult parts of the subject as identified by the students (the muddy points), and if needed, to correct common misconceptions identified during the clicker questions or exercises.

After class, students will work on assignments (e.g. in Mastering Chemistry) designed to help them practice, consolidate, synthesize and integrate the outcomes into their 'big picture'. Students will have access to optional extension reading/resources for topics that spark their interest and they would like to learn more about.

Course materials to be developed:

Before class:

a. *Structured preparation assignment that may include one or many of the following:*

   I. *textbook reading (possibly from multiple textbooks if copyrights are not violated)*
   II. *video lecture (of existing online resources e.g. Khan Academy)*
   III. *online tutorials or simulations iv. simple 'do it at home' or thought experiments. Students will be given clear directions on what outcomes should be mastered before class.*

b. *a multiple choice quiz on the assigned preparation*
c. *a 'muddy point' question to be completed before class.*
d. *In some cases, we may wish to save the 'discovery' part of a topic for the class, and in these cases, we may recommend the students read the textbook section after the class (possibly in the next class preparation assignment).*

In class:

a. Bank of clicker questions covering common misconceptions and higher level topic-based outcomes.
b. Application-based in-class exercises on higher level topic-based outcomes that have been developed to address common difficulties and reinforce key concepts.

After class:

a. Mastering Chemistry homework set using topic-based outcomes.
b. Some form of assignment after each chapter to help students assess their own understanding of the concepts (metacognitive) and make connections within the topic and between topics - e.g. concept map project.

Learning/Achievement Gains Assessment (plan for how the team will assess the impact of reformed-course elements reformed course on student achievement, learning, student satisfaction with their learning and with the course)

Our assessment plan seeks to answer the following questions:

1. Does the redesigned course improve student learning?
2. Which elements of the developed course materials are effective for students' learning?
3. Are gains from the redesigned course transferrable to different instructors, and to the different student served at UNM and CNM?

4. Does the redesigned course result in reduced D/W/F rates?

1. Improved Student Performance: To monitor improvements in understanding of chemistry concepts, we will administer a pre-test and post-test adapted from an established Chemical Concepts Inventory. This test (CI) has been largely developed and was implemented in the spring of 2012. Based on the statistics of student responses, the questions in the CI are currently being reviewed for validation and the final version of the test will be completed for the fall semester of 2012. In fall of 2012, we will select a control group and a test group as different sections of CHEM 122. Both groups will take the pre-test and post-test, but only the test group will experience the redesigned course. The performance gain between the pre- and post-test from both groups and its relationship with the in-class exams and the final exam will be used as the measure for a variety of analyses of students' performance.

2. Effective Elements of Redesigned Course: We will collect and scan relevant individual student responses to exam, assignment and in-class questions based on the learning outcomes of the course for the purpose of item analysis. Online student surveys will be administered to monitor the students' perception of their learning and their satisfaction with it at least twice during the semester. We will also conduct interviews with students in the test groups for more in-depth feedback. Data from the exercises and surveys will be analyzed by Dr. Ho and discussed by the design team members for further refinement during and after each semester. The expected outcome of this process is to identify specific areas where we need improve student learning by modifying resources available before class, after class, modifying exercises or a combination of the above.

3. Potential for Successful Transfer: Given the number of sections offered per year and the turnover in instructors teaching them, ability to transfer the redesigned course between instructors is critical. Following our initial implementation of one section each at UNM and CNM, we will select different team members to teach the test groups in the spring and summer semesters. This way, within the first year, we will have at least four different instructors teaching the new, developed approach from two institutions with different student demographics. We will analyze the performance gains from all the four instructors against the performance gains from the control groups, and look for statistical differences. We will also include in our analysis instructors' comments about the new approach. We aim to develop an adoption plan of the redesigned course by all sections of CHEM 122 in the future which will establish the resources and training needed for instructors who are interested in taking on the new teaching method.

4. Reduction of the D/F/W Rate: The ultimate success of the redesign will be measured in terms of improved student success that can be sustained over an extended time period. The D/F/W rate provides an important measure of this. Given the variability of this metric from semester to semester, we recognize that this is inherently a means of longer term assessment that will add to our more immediate measures detailed above.

Timeline: (An outline of when different course-reform elements and assessments will be implemented during the next year, including the roles of each team member in each implementation step)

Summer 2012

- Pre- and post-test implementation and analysis
- development of instructional materials

Fall 2012

- section 1, 200 students, test group, Yang
- section 2, 200 students, control group, McBride
- CNM, 50 students, test group, Sorensen-Unruh

Winter break 2012

- 2 weeks before the spring starts, complete the refinement.

Spring 2013

- section 1, 200 students, test group, Knottenbelt
- section 2, 200 students, test group, TBA
- section 3, 50 students, test group, TBA
- section 5, 50 students, BA/MD students, test group, Knottenbelt
- CNM, 50 students, test group, Sorensen-Unruh

Summer 2013

- section 1, 72 students, test group, Ho
- Final report for the project