A. Foundational Information

Course number, or numbers (including department/program prefix): CHEM 131 and 132

Course name(s): Principles of Chemistry

If the redesign will affect companion laboratory or recitation/problem solving sessions that have a separate course number/title, then please list these course numbers and titles in this space: **N/A**

Typical number of sections and students taught during fall, spring, and summer semesters (listing lab and recitation/problem solving sessions separately from the lecture) for each course involved in the redesign proposal:

Fall: CHEM 131 for 50 students for the first year, and 125 students for years on
Spring: CHEM 132 for 50 students for the first year, and 125 students for years on

Purpose. What are the specific, measureable objectives of your proposed redesign project?

In the previous efforts in course redesigns, we have successfully transformed the general chemistry sequence, CHEM 121 and 122, into active learning classes. Data showed that student performance in these redesigned courses were significantly improved indicated by concept gains and improvements in comprehensive final exams. However, the reform of our general chemistry curriculum cannot be completed without considering the particular group of students who are pursuing a field that requires more in-depth and field knowledge of chemistry to lay a good foundation for them to take advanced science and engineering courses. These students were usually the high achieving students in CHEM 121 and 122 who have not been the target by the previous redesign efforts. This project is therefore a separate effort to reform our previously "honors general chemistry" sequence, CHEM 131 and 132, and to streamline the placement of students between CHEM 121/122 and CHEM 131/132 sequences. We expect the outcomes of this project will

1. provide relevant, "in context" learning to students in STEM-related fields,
2. promote student interest and skills in the application and research of chemistry and therefore improve STEM retention,
3. Establish a data-driven placement system for CHEM 121, 122, 131, and 132,
4. Improve students performance in the subsequent STEM courses that use chemistry knowledge learned from CHEM 131/132.

Significance: Why are the objectives provided above important to the recruitment, retention, and graduation of students at UNM?

The context-based, modular approach we will develop has known positive effects on student learning. First, the use of real-world questions gives students why we study chemistry, and renew their interest in pursuing STEM fields. This is an important step to reverse the existing trend that students lose interest in the subject after finishing the foundational chemistry course because of the irrelevancy of the course materials to their fields. Secondly, our context-based approach will provide students practical examples of the applications and practices so that students would taken in the advanced courses and future career. Existing models with similar philosophy such as Wright State University math pre-requisite course have demonstrated the effectiveness of this philosophy. Furthermore, establishing an effective placement to students taking appropriate general chemistry course would help each course focus on students and enable instructors to bring more effective learning strategies to students. As the results, we expect the benefit of this project is not limited to CHEM 131 and 132, but extended to the former redesign courses of CHEM 121 and 122. We believe not only the recruitment and retention of chemical related majors will be improved, but also the performance of other students in CHEM 121 and 122 will be increased. The long-term effect to other courses is subject to further investigation but with a positive prospective.

B. Preliminary Redesign Plan

1. **List the measureable learning outcomes for the redesigned (these may be the current student learning outcomes for the course or potential revisions to those outcomes).**

CHEM 131 Student Learning Objectives (SLO)

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. Explain the structure of the atoms, isotopes and ions in terms of its subatomic particles. (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. Describe physical states and changes, and distinguish these from chemical changes. (Related to HED Core Competencies Area III no. 4)
6. 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)
7. 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)
8. 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)
9. Use different bonding models to describe formation of compounds (ionic and covalent). Apply knowledge of electronic structure to determine molecular spatial arrangement and polarity. (Related to HED Core Competencies Area III no. 4)

10. Analyze how periodic properties (e.g. electronegativity, atomic and ionic radii, ionization energy, electron affinity, metallic character) and reactivity of elements results from electron configurations of atoms. (Related to HED Core Competencies Area III no. 4)
11. Apply principles of general chemistry to specific real world problems in environment, engineering and health-related fields. (Related to HED Core Competencies Area III no. 4 and Area II no. 2)

CHEM 132 SLO

1. Explain the intermolecular attractive forces that determine physical properties and phase transitions; apply this knowledge to qualitatively evaluate these forces from structure and to predict the physical properties that result. (Related to HED Core Competencies Area III no. 2)
2. Calculate solution concentrations in various units (molarity, molality, mole fraction, % by mass, and % m/v) and explain the effects of temperature, pressure and structure on solubility. (Related to HED Core Competencies Area III no. 2)
3. Describe the colligative properties of solutions and explain them using intermolecular forces. Determine solution concentrations using colligative property values and vice versa. (Related to HED Core Competencies Area III no. 2 and 4)
4. Explain reaction rates, rate laws, and half-life; determine the rate, rate law and rate constant of a reaction and calculate concentration as a function of time and vice versa. (Related to HED Core Competencies Area III nos. 2 and 4 and Area II nos. 1 and 2)
5. Explain the collision model of reaction dynamics, including activation energy, catalysts and temperature; derive a rate law from a reaction mechanism and evaluate the consistency of a mechanism with a given rate law. (Related to HED Core Competencies Area III no. 2 and 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. (Related to HED Core Competencies Area III no. 2)
7. Describe the equilibrium constant and use it to determine whether equilibrium has been established; calculate equilibrium constants from equilibrium concentrations and vice versa. (Related to HED Core Competencies Area III no. 2 and 4 and Area II no. 2)
8. Describe the different models of acids and base behavior, and the molecular basis for acid strength. (Related to HED Core Competencies 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. (Related to HED Core Competencies Area III no. 2 and 4 and Area II no. 2)
10. Explain titration curves and speciation diagrams; calculate concentrations of reactants from the former and determine dominant species as a function of pH from the latter. (Related to HED Core Competencies Area III no. 2 and 4 and Area II nos. 1 and 2)
11. Explain and calculate the thermodynamic functions enthalpy, entropy and Gibbs free energy for a chemical system; relate these to equilibrium constants and reaction spontaneity. (Related to HED Core Competencies Area III no. 2 and 4)

12. Balance redox equations, express them as two half reactions and evaluate the potential, free energy and equilibrium K for the reaction, as well as predict the spontaneous direction. (Related to HED Core Competencies Area III no. 2 and 4)
13. Construct a galvanic or electrolytic cell; determine the standard (and non-standard) cell-potential of the former and relate current to electron transfer rates in the latter. (Related to HED Core Competencies Area III no. 2 and 4).

2. At this preliminary point in your planning, how do you plan to assess student achievement of the outcomes stated in #1?

From the curricular point of view, we desire to make CHEM 131/132 sequence equivalent to CHEM 121/122 sequence so that students can switch between the two sequences when their career goal changes. Therefore, the two sequences should cover the same chemistry content and semester break-down. Consequently, we will develop the same or similar SLOs for CHEM 131 and 132 as those of CHEM 121 and 122. It is therefore, advantageous to implement the same assessment strategies to the CHEM 131 and 132 SLOs as for CHEM 121 and 122 we previously developed. This will include the concept inventory pre- and post-tests, and the CLASS survey, all of which will be administered in the associated lab courses CHEM 123L and 124L, common core questions, and common final exam, which will be implemented in the classroom. The new measures will include ALEKS placement test that will be given before the registration. The following is a timeline for these assessments:

pre-semester	wk1		through		wk16	wk17
ALEKS	Pre-tests*	<------	common-core question throughout the semester	------>	post-tests*	Final
Online	Lab		class		lab	class

*The pre- and post-tests include the concept inventory and CLASS survey.

3. Describe the teaching methods that your are currently considering for the redesign and link these proposed methods to (a) the purpose of your project described on page 3, (b) the learning outcomes stated above and (b) to your current knowledge of research on teaching and learning processes.

We will take the context-based, modular approach to design and implement course materials. We adopt King's definition[1] of context-based approach as "A context-based approach is when the "context" or "application of the chemistry to a real-world situation" is central to the teaching of the chemistry. In such a way, the chemical concepts are taught on a "need-to-know" basis; that is, when the students require the concepts to understand further the real-world application." The context will be grouped into modules in our development of the course. Each module may consists of many problems or projects to engage students in learning chemical concepts that is required for finding solutions to the asked questions. The implementation of these modules will take the form of problem-based learning[2] where peer discussions will take place in the classroom. Another unique feature of our proposed approach is the involvement of research active faculty in classroom teaching. The proposed courses will be cooperatively taught by faculty experts in different areas of chemistry. We take this approach to ensure the accuracy of the materials and for the inspiration faculty experts can bring to students with their passion and experience. More importantly, we will be engaging students with scientists on the frontiers of research. This strategy will also facilitate placement of undergraduate interns in research groups early in their research careers, which will further engage them in learning Chemistry.

Context-based approaches are generally considered effective in affective domains as well as the cognitive domains[3,4,5]. The use of contexts makes learning chemistry relevant to students' daily lives and provides students with reasons to appreciate the course content. Therefore, students in context-based courses have more positive attitudes toward Chemistry. On the other hand, there is insufficient evidence that students who take context-based approaches show superior learning in chemistry concepts compared to students who take the traditional, content-based approach. For this reason, we will focus our development of a context-based approach to enhance students' cognitive performance, particular to underrepresented students, including women and ethnic minorities.

A typical class will feature not only lectures, but also pop-quizzes on the course materials. The students will also be asked to collect and compile information on the module to be taught and discuss the materials in classroom in relation to the fundamental chemical principles. In addition, we plan to invite research active faculty in Chemistry, Biochemistry, and Chemical Engineering to lecture the current research frontiers, in order to motivate the students. We have identified several such lecturers in UNM main campus, the north campus, Sandia Labs, and Air Force Research Lab.

4. Describe your preliminary plan for expanding the redesign to include all sections of the affected course or courses.

The context-based modules will be designed in two years. During this developing phase, we would like to collect assessment data to inform the quality and effectiveness of the modules for student learning and other objectives we stated previously. We will limit our capacity in year one to 50, and increase it to 125 in year two if a positive outcome will be granted. We can also consider if two sections of the class for the same total capacity should be offered to provide more choices of time for students. Overall, if the demand for this course will be increased due to the shift of students' interest to chemistry related fields, we will consider making the adjustment accordingly between the CHEM 121/122 and 131/132 sequences. Based on the past two semesters' data, 150 students are the projected maximum number.

The team leader (H. Guo) is a seasoned professor who has taught General Chemistry in two institutions. He is the winner of the Teaching Excellence Award in College of Arts and Sciences in 2013. He will be responsible for design, lecture and coordination of the new course. Dr. J. K. Ho is the Director of Chemical Education and has been involved in undergraduate education for many years. He will be involved in course design and in charge of assessment. Dr. Habel-Rodrigues has been teaching chemistry course after her graduation from this department, and is known for her dedication and enthusiasm. She will be involved in both course design and lectures. Her involvement will be vital in serving as a role model for under-represented student populations in this class.

5. Explain how you plan to sustain, and improve upon, the redesigned course components following the one-year funded redesign effort.

As explain previously, it will take two years for all modules to be fully developed. During this period, revisions will be done as much and as soon as possible. The basis of the revisions will be the assessment data we collected throughout the project. During this project period, the member's responsibilities are divided as follow:

- Module development and implementation: Guo, Habel-Rodrigues
- Assessment and data analysis: Ho

After the completion of the development of the course, the department's Chair will provide the provision for the continuation of the implementation of the redesign work.

References:

1. 1 King, D. New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education* 48, 51-87 (2012).
2. Allen, D. E., Donham, R. S. and Bernhardt, S. A. Problem-Based Learning. *New directions for Teaching and Learning,* 128, 21-29 (2011)
3. Gutwill-Wise, J. P. The Impact of Active and Context-Based Learning in Introductory Chemistry Courses: An Early Evaluation of the Modular Approach. *J. Chem. Edu.* 78, 684, doi:10.1021/ed078p684 (2001).
4. Jong, O. D. Context-based Chemical Education: How to Improve it? 19th ICCE (2006).
5. Bulte, A. M. W., Westbroek, H. B., de Jong, O. & Pilot, A. A Research Approach to Designing Chemistry Education using Authentic Practices as Contexts. Int. J. Sci. Educ. 28, 1063-1086, doi:10.1080/09500690600702520 (2006).

Certifications

All team member must sign* below, acknowledging the following:

- ✓ Commitment to attend the Designing Courses for Effective Student Learning course-redesign institute; May 14 and15 (9 am to 3:30 pm each day) and May18 (8:30 am to 12:00 pm), 2015
- ✓ Commitment to participate in the course-redesign effort continuously from May 2015 through June 2016 including a commitment to the five elements for a scientific approach to optimization of science education
- ✓ Commitment to implement the course-redesign elements when teaching the redesigned course during the 2015-2016 academic year, including classroom observations by project staff, and possible administration of surveys to students
- ✓ Commitment to attend at least 8 of the 12 teaching professional development activity sessions throughout the year and are responsible for following up with your team after the activity sessions
- ✓ Agreement with the content of this proposal

In addition, the *team leader* is responsible for the following:

- ✓ Collecting and submitting evaluation data
- ✓ Coordinating and facilitating team meetings
- ✓ Distributing tasks and responsibilities among team members in a manner agreed upon by the team
- ✓ Preparing the annual report at the end of the first year
- ✓ Responding to inquiries and correspondence from STEM Gateway

UNM faculty team member (leader)

Printed name H. Guo

Signature HG

UNM faculty team member

Printed name K. Joseph Ho

Signature

UNM faculty team member

Printed name D. Habel-Rodriguez

Signature Diana Habel-Rodriguez

UNM faculty team member

Printed name ______________________

Signature

*If is it not readily possible to obtain all signatures at the time when proposals are due, each unsigned team member may send an email to Gary Smith (gsmith@unm.edu) that lists and acknowledges the commitments and agreement listed above.

Supporting Letter

Proposals must include a letter of support from the Department Chair that (a) certifies that the redesign proposed in the target course has broad support from the unit, and (b) provides assurances that all sections of the course will implement the redesign by the third semester. (It is expected that all sections of targeted courses will utilize the new models developed, but project implementation might only involve a select number of pilot sections during the first semester).

THE UNIVERSITY of NEW MEXICO

Stephen Cabaniss, Professor and Chair
Chemistry & Chemical Biology
MSC03 2060, 1 University of New Mexico
Albuquerque, NM 87131
Phone: 505.277.6655

March 12, 2015

Prof. Gary Smith
STEM Gateway Course Redesign Project

Dear Prof Smith:

I am writing in strong support of the redesign proposal for CHEM 131 and 132 being submitted by Drs. H. Guo and K.J. Ho. As you know, our department has experimented with several different pedagogical and curricular modifications in introductory chemistry, including the “parachute” course (CHEM 120), the creation of Chemistry in Our Community (CHEM 101) for non-science majors, and the active-learning redesign of CHEM 121 and 122; the planned re-launch of CHEM 131 and 132 is the next step in updating our introductory chemistry curriculum.

Chemistry and Chemical Biology (CCB) has offered CHEM 131L and 132L for many years as a general chemistry track for 'advanced' students. However, the course has never generated consistent enrollments, and has not produced many Chemistry majors. Possible reasons for this include changing instructors and mission of the course, which has variously been regarded as an 'Honors' course, or for intended Chemistry majors only or for students with good chemistry background (not the same groups). The courses have not been offered every year, which may have also contributed to low enrollments.

CCB faculty recently decided to re-launch this sequence to better prepare students intending to major in the chemical sciences (Chemistry, Biochemistry and Chemical Engineering). Our intention is to engage students who may have interest in the area by teaching general chemistry concepts as they apply to current research topics. The CHEM 13x track will be taught by faculty with active (or recently active) research programs and will require a multi-year effort to develop new curricular materials, but should result in better student engagement and retention within the majors.

CCB is committed to implementing the CHEM 131-132 sequence for the next four years (at least) to determine its effect on major selection and retention, and will provide continuing funds to support materials development.

Thank you for considering our proposal. If you have any further questions, please do not hesitate to contact me at 272-6655 (Office Phone) or by e-mail at cabaniss@unm.edu.

Sincerely,

Steve Cabaniss
Digitally signed by Steve Cabaniss
DN: cn=Steve Cabaniss, o=University of New Mexico, ou=Dept. Chemistry and Chemical Biology, email=cabaniss@unm.edu, c=US
Date: 2015.03.12 15:52:15 -06'00'

Stephen Cabaniss, Professor and Chair
Chemistry & Chemical Biology