CHEM 121 Course Redesign Annual Report 2014

1. *Project motivation and goals:* A brief explanation of the motivation of the redesign project and the goals that were established at the outset (along with any modification of goals that were developed during the year)

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 intended 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 proposed to improve student motivation, learning and retention in CHEM 121 by a course re-design emphasizing active learning, interdisciplinary exercises and multi-component assessment.

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 used 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 is 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 are used to assess learning in these exercises, but also as a tool to promote student participation and engagement.

Exercises utilize 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. A major focus of our redesign was to target known misconceptions and student difficulties and we aimed 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 allow the exercises to be textbook independent. Peer learning facilitators were employed in larger sections to ensure that student groups remain "on track" during in-class exercises.

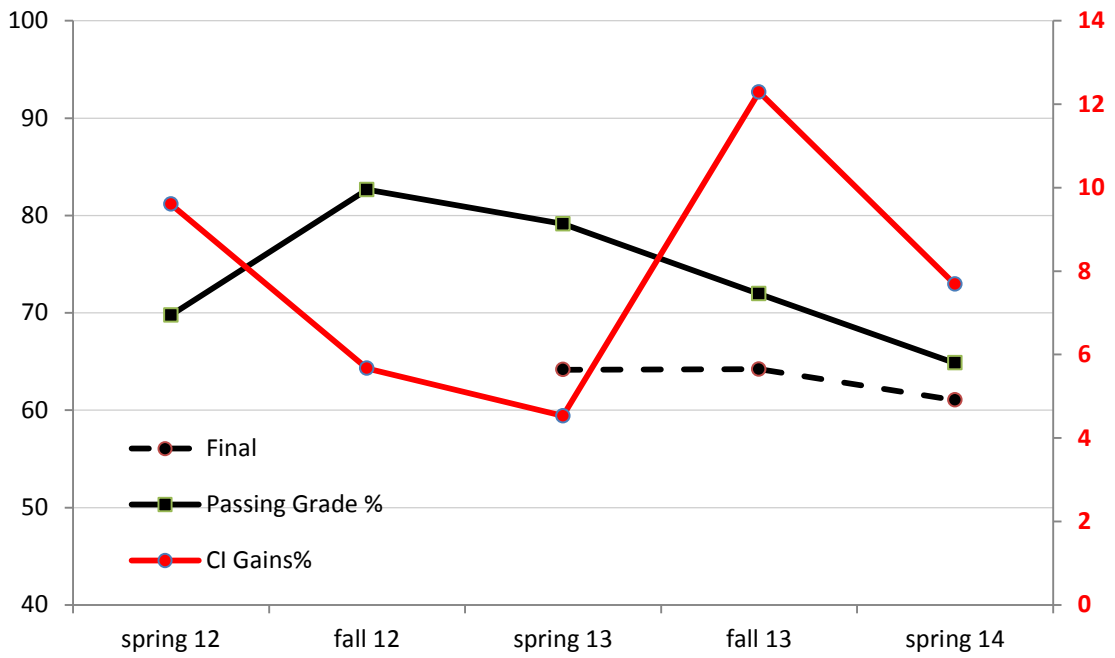
2. *Project summary:* Summarize the instructional redesign components (this will likely come from the proposal along with modifications that may have been made)

    - Established course learning outcomes that align with HED competencies and STEM major requirements. This was done in the summer of 2013.
    - Developed structured pre-class reading assignments and formative assessments to enable students and instructors to monitor acquisition of basic facts and concepts before class. This was done in the summer of 2013 and revised during the winter break of 2013/2014.
    - Created in-class, interdisciplinary exercises and questions which require higher-order thinking with optional follow-up references. These are combined with clicker questions that test these higher levels of thinking for assessment in the large classes. This was done in the summer of 2013 and revised during the winter break of 2013/2014.
    - Created a detailed multicomponent assessment plan for the initial implementation. The assessment includes modified chemistry concept inventory, implemented as pre- and post-test, common core questions in four 50-minute exams, and a common final exam. These assessments were implemented in the fall and spring semesters of 2013 and 2014. The pre-test was implemented during the first week of each semester and the post-test during the week 16 of each semester. The common core questions were given by all sections during the same week. The common final exam was written by faculty not teaching CHEM 121 during these semesters, and implemented during the scheduled final exam time using scantrons. Data generated from all assessments mentioned were analyzed and discussed – see the conclusions in the assessment section.
    - Developed subject-specific training for learning facilitators (TAs, SI and PLFs in the classroom). Each faculty member provided section-specific training for their learning facilitators, and discussion included common student errors on course materials as well as general trouble-shooting on issues raised by the facilitators.

3. *Assessment:* Present any and all data obtained as part of the originally stated or modified assessment plan that are related to students' (a) learning (e.g., outcomes assessment data, pre/post-test or concept-inventory results), (b) success (e.g., grades), and/or (c) attitudes (e.g.,

surveys). These data should be briefly interpreted.

A. Normalized concept gains, comprehensive final exams and percentage passing rate



The trends of the final exam averages, normalized gains averages, and percentage passing grade average in the last 5 semesters were summarized in the figure above. The fall semester of 2013 is the first semester we implemented the redesigned CHEM 121 material. The averaged normalized concept inventory gains data of fall 2013 showed a significant surge. Although the gains in the spring semester of 2014 dropped, they are still higher than the corresponding spring 2013 semester, and we believe the average gains will reach an equilibrium in the near future, similar to the trend we observed in the CHEM 122 redesign. A greater spectrum of students' background and maturity in CHEM 121 are also contributing factors for such wide fluctuation of the performance.

The slight decline of percentage passing rate has many possible reasons that are not related to the trend of concept inventory gains. Before the spring of 2013, while the average concept gains declined, the passing rate increased. When the gains increased in the fall of 2013, the passing rate decreased further. We believe the contributing factors to the decline of passing rate are not directly related to student's performance in the pre- and post-concept inventory tests or the final exams. Other factors in the final calculation of course grade might be determining effect of such decline. Among them, the homework assignments and in-class discussions are two main factors, as well as individual faculty member policies.

Although the trends shown here are not as encouraging as we would hope, we believe the changes from semester to semester can be explained by the standard deviations of the means and a longitudinal study will provide an opportunity for more data collection to resolve this uncertainty. We should delay our conclusion at this point about the effect of

redesign courses on student's performance.

B. Students' Mathematical Background and their performance

Fall 2013

grade	121	123	150	162	163	180	ACT/SAT
A	10.1	20.0	11.1	45.5	60.0	22.2	30.8
B	24.7	35.0	55.6	54.5	40.0	33.3	27.0
C	25.8	30.0	11.1	0.0	0.0	22.2	16.5
D	13.5	15.0	0.0	0.0	0.0	11.1	8.9
F	7.9	0.0	22.2	0.0	0.0	11.1	4.0
W	18.0	0.0	0.0	0.0	0.0	0.0	12.7
ABC	61	85	78	100	100	78	74
DFW	39.3	15.0	22.2	0.0	0.0	22.2	25.6

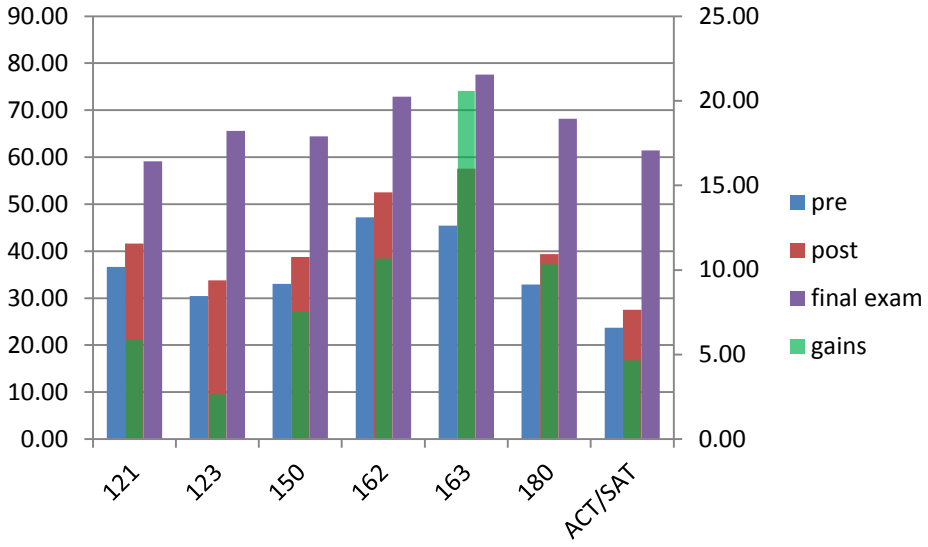
The above table was generated to show the CHEM 121 grade distributions from students taking a particular math course (121, 123, etc) a semester prior to taking CHEM 121. For example, column one contains students in CHEM 121 for the fall of 2013 who had taken Math 121 in the Spring of 2013. Among these students, 10.1% got an A, 24.7 % got a B, etc. Overall, 39.3% of these students failed CHEM 121.

From the above table, students from the two calculus courses have 100% passing rate, and generally speaking, the higher number math course students took, the greater the passing rate in CHEM 121. Students used ACT or SAT scores as the pre-requisite for CHEM 121 have the passing rate similar to higher Math course number, such as 150 and 180. We can therefore, conclude that completing MATH 121 is not equivalent to ACT/SAT requirement in terms of math preparation for chemistry.

C. *Correlation between Math courses & Assessments (spring 2014)*

Math courses	Pre	post	gains	final exam
121	36.63	41.64	5.86	59.15
123	30.45	33.77	2.65	65.57
150	33.03	38.79	7.52	64.41
162	47.22	52.53	10.68	72.86

163	45.45	57.58	20.59	77.56
180	32.92	39.39	10.32	68.17
ACT/SAT	23.69	27.50	4.65	61.46



The first table contains the averages of each assessment students in CHEM 121 scored (out of 100) based on the Math course they took in the previous semester. Once again, students took calculus (MATH 162 and 163) have higher pre and post score, and the highest gains (10.68 and 20.59%). From other math courses, the higher the course number, the greater the gains. In this case, students from ACT/SAT group scored about the same as those came from MATH 121.

D. Mid-term assessment data

We pinpointed topics of concern by discussing common midterm questions on which students did not perform as well as expected, using these as a guide for revising or adding material for future terms.

One area of concern tracked by the common midterm questions was students' well-known difficulty conceptualizing mass on the atomic scale. For example, students were asked the mass of one atom of carbon-12; many students incorrectly chose '12 g' or 'both 12 g and 12 amu' instead of '12 amu'. Instructors targeted this concept as one for additional in-class exercise work. Subsequently, percentages of students answering the question correctly increased from 37.3% to 49.5% in sections taught by the same instructors the following term.

E. *Student and faculty attitudes toward redesigned courses*

In general, students' responses to the redesign have been favorable. Responses solicited from instructor surveys include:

- "Class is interesting and the worksheets give me a good idea of what kinds of questions to expect on an exam. Because we work through example problems in class every day I feel more comfortable with the material and don't have to study

outside of class as much as I normally would. Practical application is the best way for me to learn a concept or equation."

- "I enjoy this class very much. Although it is challenging and a lot of work, I enjoy the challenge and the in-class exercises and being able to work in groups and ask questions throughout is extremely helpful as opposed to just a straight lecture class."
- "The in-class work and working in groups really helped me a lot because not only could I ask for help from the PLF and professor, my classmates made it easier for me to understand what the concept was about."
- "Because we are expected to read certain sections before class, … lecture leaves out a lot of information that makes it so the people who had to work late or just didn't get to do the reading are completely lost."

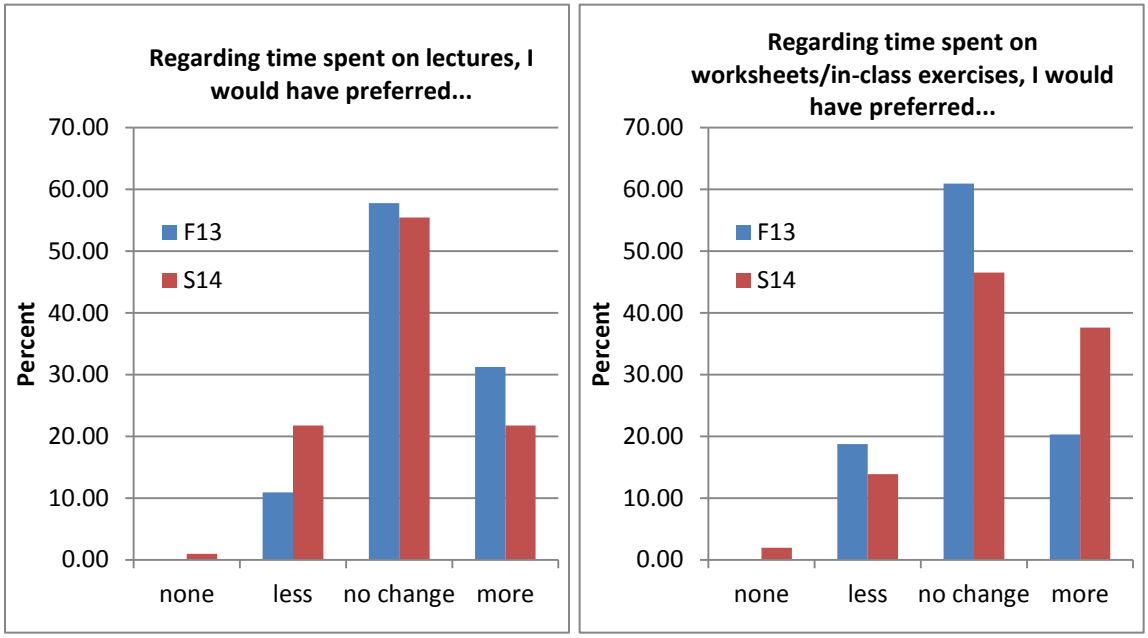
One instructor asked students to report their attitudes toward the active learning aspects of the course redesign (specifically, in-class exercises, PLF-supported group work, and clickers were used); in Fall 2013 there were 64 respondents; in Spring 2014 there were 101 respondents.

Students overwhelmingly appreciated in-class exercises and group work opportunities. Specifically, they pinpointed the ability to work with their peers and access differing methods for approaching the same question as one of the key benefits to the redesigned course; several students also appreciated having immediate access to PLFs and/or the instructor to resolve questions or provide aid. The most common negative points involved dissatisfaction with the grading scheme or the amount of time spent on lecture versus in-class exercises.

	Fall 13 n= 58	**Spring 14 n= 87**
In-class exercises/clickers were beneficial to learning	46 (79.3%)	73 (83.9%)
… because working with peers was valuable/hearing different perspectives or methods of solving a problem was useful	11 (18.9%)	29 (33.3%)
… because I was able to receive immediate help from PLFs and/or my instructor	7 (12.0%)	14 (16.0%)
… but working as a group should be incentivized/more encouraged	0 (0%)	2 (2.29%)
The grading system (correct = 2 points, incorrect = 1 point) should be changed	2 (3.44%)	6 (6.89%)
A different order of clickers vs lectures would have been better	5 (8.62%)	4 (4.59%)
In-class exercises were not beneficial or detrimental to learning	6 (10.3%)	7 (8.04%)
… because they took away from lecture time	5 (8.62%)	3 (3.44%)

As shown in the two graphs below, when asked specifically about the time management of class activities, significant numbers of students wanting some adjustment. However, there was no consensus on what specific adjustments should be made (in these particular sections of 121, roughly equal amounts of time were spent on lecture and active

learning).



Faculty responses to incorporating the redesign were also generally favorable. Instructors generally reported an increase in student engagement with the material, student engagement with the instructor, attendance increases, but also that switching methods had a steep learning curve. Encouragingly, several instructors have gone on to incorporate active learning techniques in higher level courses they teach (e.g., organic) and an instructor who did not participate in the redesign in Fall 2013 chose to incorporate redesign elements in Spring 2014.

- "Having spent many semesters thinking about how to improve student learning in General Chemistry and trying out different tactics in isolation, being a part of the course redesign teams has been invaluable. The opportunity to share my own experiences and learn from ideas and responses from others has helped me improve my teaching more and faster than I was able to do on my own."
- "My biggest challenge, compounded by being a new instructor, was time management of lectures vs in-class work."
- "Having the strong faculty community and pre-prepared materials available for modification was invaluable…"
- "When prepping for the first semester of teaching 121, I found using all of the redesign a bit overwhelming, so I decided to pick and choose, and gradually add pieces in over several semesters."

4. *Improvement:* Provide a summary of the curricular and pedagogical changes you are planning to make in light of the collected assessment data and your teaching experiences.
   - Using ALEKS as the pre-semester preparation for students. Assessment data showed that

students in CHEM 121 have various academic background and mathematical preparation. Even students who had taken high school chemistry appear to have forgotten most of what they learned in high school. We feel it is beneficial for our students to take an initial assessment about their pre-requisite knowledge before starting the semester and refresh their memories for chemistry. ALEKS is a self-paced program for this purpose. We will offer ALEKS to students in the fall semester of 2014 two weeks before the semester starts and extend two weeks after the semester starts. Students' performance will be monitored and analyzed for any difference between those who practice ALEKS and those who do not. During Winter Break, we will determine if use of ALEKS will be continued in the spring or not.

- Online lecture: we will explore the possibility of developing online mini-lectures in support of student learning where we feel that the textbook reading assignment does not seem to adequately prepare students for class.
- Assessment methodology. Instead of looking at assessment data in the aggregated manner (mean values of test results), we will start to look for performance trend based on groups of students, such as quintile or social-economical status. We will also like to asses questions like "How many students read the textbook?" and "Is Mastering Chemistry effective for our students' learning?" We also like to obtain more data about student's perspective of the reformed course using surveys.
- Continue refinement of course material and assessment questions. A list of difficult concepts and misconceptions has been constructed from item analysis of the final exam. We will generate new material to address these difficult concepts to be used in the fall semester. Ineffective questions from the past assessments were also identified using the scantron reports. These questions will be either modified or avoided in the next assessments used for fall and spring semesters.
- Interdisciplinary exercises can motivate students by the area of application and the level of conceptual integration, and engage higher-order reasoning skills. We should develop more 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

5. *Expansion:* Outline your plan for continuation of the redesign project, which should include an indication of the approximate number of sections of the course that will be taught using the redesign in Fall 2014 and Spring 2015 and (b) who the likely instructors will be and/or how those instructors will be recruited. If, compared to Spring 2014, there will be no increase, or there is a decrease, in the number of sections taught with the redesign, then please provide a rationale.

   All sections of CHEM 121 participated with some aspects of the redesign in Fall 2013 and Spring 2014. We have included all sections of our CHEM 121 in our reformed project in the fall semester of 2014 and intend to continue this arrangement in the near future. No expansion plan is necessary for our team.

6. *Sustaining*: A plan for sustaining the curricular and pedagogical innovations of the redesign. This section should include (a) achievements and/or intentions for accessible curation and dissemination

of redesigned instructional components, (b) plans for continued work by the team to assess outcomes and make adjustments for continuous improvement, and (c) plans for assuring successful, self-efficacious implementation of the redesigned course elements by instructors who were not part of the original team.

- We have found the faculty weekly meeting to be very effective for sustaining practice of the reform effort, as well as supporting instructors who are new to the style of teaching. At these meetings, instructors set core exam questions, discuss assessment results and troubleshoot issues together that individual instructor's face. We will continue this practice indefinitely.
- We will implement a faculty start-up meeting to better coordinate the reform effort and training for faculty members first-time teaching CHEM 121.
- Conference presentations. We have presented our project in Success in the Classroom, New Mexico Higher Education Assessment & Retention conference, NSF Analytical Chemistry Active Learning workshop, and will present in Biennial Conference of Chemical Education in August.
- A Departmental Website will be created in the fall to host reform material for New Mexico higher education communities and provide social network for faculty who wants to adopt the practice.

All team members should participate in these processes and teams are encouraged to commit to some face-to-face meeting time for that purpose. STEM Gateway redesign project staff will attend a session with each team at the beginning or very early during these summer activities, at any time during the summer at the request of the team leader (or individually with team members), and will also meet with each team leader after submission of the report.