In Fall of 2013 the Department of Chemistry and Biochemistry moved into the new Baker Center for Science and Mathematics. Accompanying this move was a pedagogical shift in our first-year chemistry courses from traditional, separated lecture-lab delivery to an integrated lecture-lab or "studio" approach. One general chemistry track (CHEM 124, 125) had been taught in this style for many years, thus the studio concept was not new to our department. Our move into a facility where we had designed and built four studio classrooms allowed us to expand the studio concept to nearly all of our first-year chemistry offerings. During the 2012-2013 academic year the department of chemistry and biochemistry chose to begin a long-term assessment of the effectiveness of our studio classrooms as we made this transition. This assessment was performed initially on CHEM 127, a course that had not previously been taught in the studio format, and includes assessment of both student performance as well as student attitudes towards learning chemistry.

In total 683 students are included in this study and their demographics are summarized in the table on the next page. More students come from the College of Science and Math than from any other college although a significant number of enrolled students come from both the College of Agriculture Food and Environmental Sciences and the College of Engineering. Very few students come from the University's other colleges. It may appear that less than 10% of the students who enroll in this chemistry course are first year students, but this is because a large number of students have some form of transfer credit from their accomplishments in high school or at another university; this is reflected in their Class Standing. No information on gender or ethnicity was collected for this study.

Student performance was measured through the administration of a final exam at the end of the quarter. The exam was common to all students in any given term and few of the questions change across different terms. To make the most objective comparison possible between two terms, we used the 39 questions that the two exams had in common from fall 2012 and fall 2013.
To measure the effects of a studio style course, we compared the student performance from several traditional sections offered in fall 2012, to several studio sections in fall 2013. This split plot experiment is lacking the ideal random assignment of students into traditional and studio courses as all students from 2012 are enrolled in a traditional course and all students from 2013 are enrolled in a studio course. This clearly confounds the effect of studio courses with the year in which students enrolled in the course, but was necessary to keep the course offerings consistent for all students in a given term for fairness purposes and administrative costs.

To minimize the effect of the confounded factors we included a diagnostic assessment (California Chemistry Diagnostic published by The American Chemical Society), given at the beginning of the term, as a control to ensure any changes we observed were not explained by a change in the incoming student population. The diagnostic exam allows us to compare students of a similar level of preparedness, but it does not allow us to completely distinguish between the impact of the studio courses and that of the changes in the department from 2012 to 2013. To account for other sources of variance present in this setting, we have also included controls for the four participating instructors and a 1 unit supplemental workshop in which some students enrolled.

To assess student attitudes about learning chemistry, we decided to give an attitude survey at the beginning and end of each quarter. We gave the Colorado Learning Attitudes about Science Survey, also known as CLASS, for Chemistry. The CLASS has 50 statements that students respond to on a scale from “Strongly Agree” to “Strongly Disagree.” The statements are broken up into 11 categories and are either worded favorably (an expert agrees) or unfavorably (an expert disagrees). A high score is indicative of a more expert-like attitude for favorable statements and is indicative of a more novice-like attitude for unfavorable statements. The 11 categories that the statements are broken up into are: Overall (Ov), All Categories (AC), Personal Interest (PI), Real World Connection (RWC), Problem Solving General (PSG), Problem Solving Confidence (PSC), Problem Solving Sophistication (PSS), Senses Making/Effort (SME), Conceptual Connections (CC), Conceptual Learning (CL), and Atomic-Molecular Perspective of Chemistry (AMP).

PLOs 1 and 4 are objectives centered on student mastery of concepts and abilities central to learning chemistry. Assessing the effectiveness of our studio approach in our first-year chemistry offerings through the methods described above seems well aligned with both PLO 1 and PLO 4. As described below, the methods we have employed in this assessment allows for quantitative measurement of learning gains associated with the studio classroom.

1. **Analyze the results of the assessment.**

   *Diagnostic Assessment*
A diagnostic assessment was given to all students at the beginning of the quarter to control for the differences in students’ preparedness at the beginning of the quarter and to see if student differences had a significant impact of the efficacy of the other factors. We can see in the figure to the right that students who did well on the diagnostic exam at the beginning of the course, unsurprisingly, did well on the final exam at the end of the course. Perhaps the more interesting finding is that the other factors do not interact with the students’ diagnostic score. That is, students realize a uniform benefit from studio courses and supplemental workshops. The benefits of these programs are not related to how well prepared the student was at the beginning of the quarter.
Instructor Studio Interaction
The figure to the right shows the instructor effect in a traditional style course in green and a studio style course in red. While students always perform better in studio courses, students enrolled with some instructors may benefit more than those enrolled with other instructors. Like the instructor effect, this could be a result of any number of differences between the different instructors and learning assistants in the studio courses, or even just the students in the particular section. Further studies will include analysis over more sections and focus on maximizing this benefit. For our analysis, it is sufficient to say that different instructors capitalize on the studio style courses more effectively than others.

DFW Rate
Another metric used to assess the success of the studio style courses was the DFW rate. The DFW rate is the proportion of students who withdrew from the course or received a grade of D or F. Figure shows the DFW rate from 2004 to 2014 where studio courses are shown in blue and the traditional courses are shown in red. The DFW rate has shown significant variability and a slight downward trend over the last ten years, so while the studio courses have a slightly lower average than the traditional courses, it is not significantly different given the variability. Furthermore, the DFW rate of the studio courses seem to follow the general downward trend of the data, so no conclusions can be reached from the analysis of the DFW rate.
Student and Instructor Evaluations
We asked students and instructors their opinions about how the studio compares to a traditional course with surveys. The participants answered each question on a Likert scale from 1 to 5. We simplified their responses to agree, disagree and neutral with a rating of 3 being neutral. The student responses, shown in the figure to the right, were very positive; the students clearly prefer studio style chemistry over what they perceive the traditional course would be like. The instructor responses, shown below in the figure to the right, are also all positive or neutral. Instructors and students generally feel that studio style courses are at least as good as traditional style courses.
**Student Attitudes Towards Learning Chemistry**

As mentioned previously we used the CLASS instrument to assess student attitudes towards learning chemistry. We tracked students through the CHEM 127, 128, 129 sequence during F2012, W2013, Sp2013 quarters. The survey was administered at the beginning and end of each quarter. There are 519 surveys included in the Fall quarter, 499 in the Winter quarter, and 258 in the Spring quarter. In the graph to the right, the lines are student attitude shifts over a quarter, the top set of lines are for the “favorable” statements and the bottom set of lines are for the “unfavorable” statements. The pink dots above lines indicate categories that showed a significant shift (more than two standard deviations from the mean). This graph includes all students surveyed in each quarter. There is a small general increase in expert-like student attitudes over fall quarter (with the exception of RWC) and a general decrease in expert-like student attitudes over both the winter and spring quarters. Most of the fall shifts are significant while only about half of the winter and spring shifts are significant. Another noticeable trend is that expert-like attitudes increase between the end of one quarter and the start of the next; this is called the “Winter Break Effect.” We also see that the attitudes at the start of the spring quarter tend to be more expert-like than at any other point during the year.

If we eliminate the pre data for the winter and spring quarters and construct a graph using pre-fall, post-fall, post-winter, and post-spring surveys we see (figure to the right) there is a general overall increase in students having a more expert-like attitude from the first day of Fall quarter to the last day of Spring quarter. In only two of the categories there is a slight decrease in expert-like attitudes throughout the year, but in the other four categories there is either a large increase in expert-like attitudes or very little change in attitudes over the year.
**Summary**

We have found that students enrolled in studio courses score about 9% higher on the common final exam than students who are enrolled in a traditional class with separate lecture and lab sections. Because of the controls included in the model, this improvement is independent of other factors that may impact the student’s grade like which section they were enrolled in or how prepared they were at the beginning of the course. The raw data shows that even with no controls, students in studio courses earned more A (>90%) and B (between 80% and 90%) grades and fewer C, D, and F grades on the common final exam.

We also found that enrollment in the Supplemental Workshop Section was correlated with a 4% improvement in student grades, but it is not clear how much of the improvement is from attending the workshop and how much is simply because the students who elect to enroll in the workshops are more determined to succeed.

Lastly, students and instructors both responded very positively to the studio classroom when surveyed. A majority of students agreed with all favorable statements, and disagreed with all negative statements, regarding studio courses. A majority of instructors usually agreed with favorable statements as well, but most instructors were neutral regarding how studio courses effect student motivation.