

Mastering Chemistry

School Name University of Hawai'i at Hilo, Hilo, HI

Course Name General Chemistry II

Course Format Face-to-face

Key Results Evidence from this study shows that, each semester, students who attempted more required Mastering Chemistry assignments and performed better on optional Adaptive Follow-Up assignments tended to have final exam scores that were at least 11 percentage points higher.

Submitted by

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Course materials

Mastering Chemistry and *Chemistry: A Molecular Approach*, Nivaldo J. Tro

Setting

The University of Hawai'i at Hilo enrolls approximately 4,000 students, 25 percent of whom indicate they have precontact native Hawaiian ancestry.¹ The graduation rate for the cohort starting fall 2007 was 36 percent within six years, and 67 percent of the cohort received either a Pell Grant or subsidized Stafford Loan.²

Instructor Natalie Crist has been teaching at the school since 2013. She teaches General Chemistry I and II (lecture and lab), Introduction to Chemistry, and a 400-level Instrumental Analysis course. She has taught General Chemistry II for three semesters as a face-to-face course, the only format offered at this campus. While Mastering Chemistry was in use when Crist joined the school, she also used it at her previous institution.

General Chemistry II is a three-credit course, and a continuation of General Chemistry I, which is a prerequisite for the course. Students must have earned a C or better (not C-) in General Chemistry I to enroll in the course. The lab is taken as a separate course.

Upon completion of General Chemistry II, students should be able to describe concepts and demonstrate proficiency in solving numerical problems associated with chemical equilibrium and kinetics, acid/base chemistry, and electrochemistry.

Challenges and Goals

Crist believes that students need frequent problem-solving practice to learn chemistry concepts. She observes that students seem to understand the examples in class, but often struggle when trying to do problems on their own. In addition, because students need frequent problem-solving practice, grading paper-and-pencil homework in a timely manner in large classes can be an issue.

For those reasons, instructors at the University of Hawai'i at Hilo use Mastering Chemistry to administer graded homework. It enables instructors to better monitor student understanding of concepts prior to high-stakes exams and provides timely and regular feedback to students as they complete assignments. By using the hints and feedback in Mastering Chemistry, students can get help when they need it, and the program's diagnostics help instructors gain a better understanding of misconceptions in the class.

Given the course challenges and goals, Crist engaged in this study to begin to test and measure the relationship between (1) engagement in ongoing repetition and practice to fill knowledge gaps and (2) performance. To begin to measure the ways her students engaged in this type of homework and practice, Crist collected data related to Mastering Chemistry assignments that she believed would be helpful for and aligned to the learning outcomes of the course.

Implementation

Course grades for General Chemistry II for the period of this study were based on performance on Mastering Chemistry assignments, exams, and in-class quizzes. Mastering Chemistry scores included all required homework assignments, extra-credit Adaptive Follow-Up assignments, and the in-class Learning Catalytics exam review exercises.

Problems similar to the Mastering Chemistry homework were discussed in class, and the problems in the assignments then

¹<http://hilo.hawaii.edu/catalog/about-students>.

²<http://hilo.hawaii.edu/catalog/graduation-and-persistence-rates>.

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had different values or were slightly more complex scenarios designed to develop critical-thinking skills. Crist's goal with the homework was for students to make connections between topics and applications, rather than memorizing methods to solve a problem. She also encouraged students to use homework as an opportunity to make mistakes, but understand those mistakes so they weren't made again in the future.

Required weekly Mastering Chemistry chapter assignments included a mix of end-of-chapter and tutorial questions. Students were allowed four attempts per question, five percent was deducted for each incorrect response, and assignments were due by 11:59 pm every Monday. For each day late, 25 percent was deducted.

Additional extra-credit Mastering Chemistry assignments included the Introduction to Mastering Chemistry, Adaptive Follow-Up (AFU) sets, and the last assignment of the semester. For AFUs, no test-out option was available. Students earned extra credit only if they completed AFU assignments.

Learning Catalytics was used for in-class exam review, and was held one period prior to an exam. Questions were concept reviews designed to help students understand what they needed to study. Scores were calculated with 80 percent of the score from participation and 20 percent from correct answers.

For fall 2014 and spring 2015, class time typically started with an in-class clicker quiz comprising three to five questions related to the prior lecture. For each question, students earned a half point for participation by answering the question and a half point for a correct answer. This helped Crist to understand if there were any misconceptions or concepts that needed review during that class period. Beginning in fall 2015, these in-class quizzes will be conducted using Learning Catalytics.

When Crist began using Mastering Chemistry, she gave one assignment per chapter that was due after the lecture on that chapter. It sometimes took two to three weeks to cover a full chapter, and she found that some students waited until close to the due date to start the assignment. To address this procrastination and increase the frequency at which students engaged with the materials, she changed the required Mastering Chemistry chapter assignments to weekly, thereby forcing students to review the material closer to when it was covered in class.

Weekly due dates were consistent to help students remember to do homework, and to encourage them to more frequently interact with course concepts. In addition, Crist used diagnostic data to understand student performance. When students had questions, she could pull up their assignments, review problems with them, and more easily identify their particular issues.

Assessments during this study included four term exams and a comprehensive final exam, all paper-and-pencil exams done in class. Term exams were worth 50 points each and consisted of 10–15 multiple-choice questions (each worth 2 points) and short-answer questions worth a total of 20–30 points. Students were allowed to bring a calculator and one 3 x 5 notecard with anything they wanted written on it, front and back. No equations were provided on the exam, but constants were provided.

The final exam was worth 140 points. For fall 2014 and spring 2015, the 2010 General Chemistry 2nd Term Exam from the American Chemical Society (ACS), which covered all material associated with second-semester general chemistry, was administered.

Assessments

45 percent	Exams (four)
25 percent	Final exam (ACS 2010 General Chemistry 2nd Term Exam)
20 percent	Mastering Chemistry (all required and optional work)
10 percent	In-class quizzes

Results and Data

An analysis was done of the fall 2014 and spring 2015 data to understand the relationship between Mastering Chemistry use and student learning and course outcomes. Students who did not take the final ACS exam are not included in the analysis, even if they did not officially withdraw. For fall 2014, 3 out of 94 students are not included in the analysis; for spring 2015, 2 out of 66 students were not included. All of these students stopped taking exams after exam 3.

To better understand student performance and participation with the different types of Mastering Chemistry assignments, a separate analysis was conducted of the required chapter

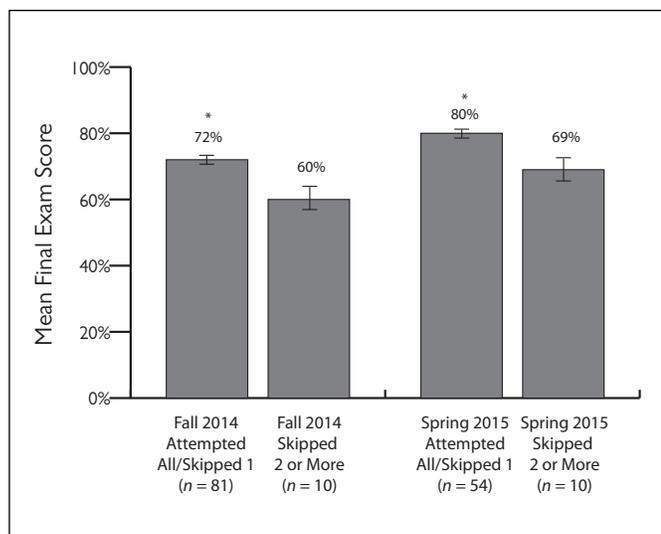


Figure 1. Mean Final Exam Scores Based on Mastering Chemistry Chapter Homework Participation, Fall 2014–Spring 2015

Err Bars = Stand Err; * $p < .05$

assignments and the optional Adaptive Follow-Up (AFU) assignments. Homework with a score of zero was considered skipped. For the required Mastering Chemistry chapter assignments, the mean number of assignments skipped for all students was one. Because chapter assignments were required, there was a high participation rate. An analysis of the chapter homework showed the following:

- For fall 2014, there were 13 required chapter assignments; for spring 2015, there were 12.
- Seventy-one percent of students attempted every required chapter assignment in the fall, and 73% attempted every assignment in the spring.
- Students who attempted more chapter assignments in the fall ($M = 72\%$; $SD = 15.58\%$; $N = 81$) had significantly higher mean final exam scores than students who skipped more than the mean number of assignments skipped (two or more) ($M = 60\%$; $SD = 14.58\%$; $N = 10$) with $p < 0.05$. The mean final exam score for students who attempted more chapter assignments in the fall was 12 percentage points higher (Figure 1).
- Students who attempted more chapter assignments in the spring ($M = 80\%$; $SD = 17.71\%$; $N = 54$) had significantly higher mean final exam scores than students who skipped more than the mean number of assignments skipped (two or more) ($M = 69\%$; $SD = 14.13\%$; $N = 10$) with $p < 0.05$. The mean final exam score for students who attempted more chapter assignments in the spring was 11 percentage points higher (Figure 1).

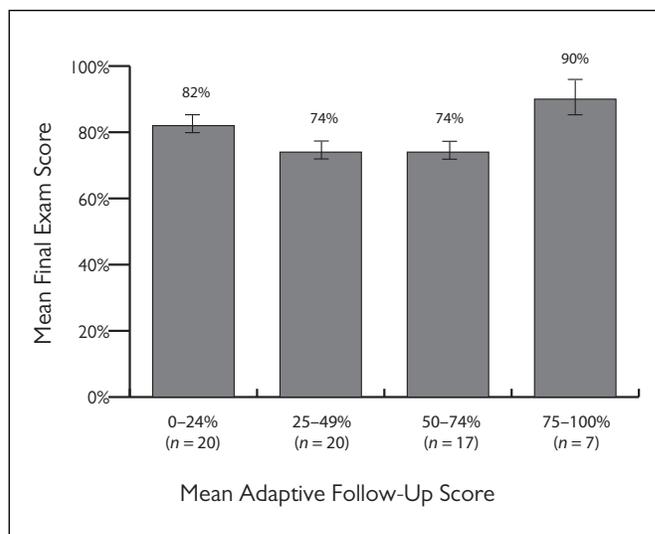


Figure 2. Mean Final Exam Score Based on Mastering Chemistry Adaptive Follow-Up Performance, Spring 2015

Student performance on optional Adaptive Follow-Up assignments was also evaluated. Since AFU assignments are generated based on individual student performance on chapter homework, each student receives different questions designed to address gaps in their knowledge. These optional AFU assignments were for extra credit, so participation rates were lower than the rates for the required chapter assignments. There were 12 AFU assignments each semester of the study, and the following results were found:

- Nine percent of students each semester attempted all AFU assignments.
- Students who earned an average score of 75 percent or higher on AFU assignments had the highest average final exam scores, and the average was statistically significantly higher than the group of students who averaged 25–49 percent and 50–74 percent on AFU assignments ($p < 0.05$).
- The group of students who earned an average score less than 25 percent on the AFUs had a higher mean final exam score than the middle groups of students who averaged 25–49 percent and 50–74 percent on the AFUs.
- The group of students who earned an average score less than 25 percent on the AFUs had a lower mean final exam score than students who averaged 75 percent or higher on AFUs. However, the mean final exam difference for the two groups was not statistically significantly different (fall 2014, $p = 0.07$; spring 2015, $p = 0.13$).
- Similar results were found in both fall and spring semesters.

Figure 2 shows the results for spring 2015. For the group averaging less than 25 percent on the AFU assignments, six students out of 20 (30 percent) were identified who did not do any AFUs, but these students had a mean final exam score of 90 percent. A possible explanation could be that these students may have felt confident in their abilities and did not feel the need to remediate, thereby skipping the optional assignments.

The study's findings may include the unmeasured influence of variables that can impact student performance, such as motivation. Data from this study suggest that based on the performance of Crist's students, those who attempted more Mastering Chemistry homework and those who attempted and scored higher on optional assignments did better on the final exam than students in the study who attempted fewer Mastering Chemistry assignments or attempted and scored lower on the optional assignments. Further research is needed to test what the initial data seems to suggest is a relationship between (1) attempting Mastering Chemistry assignments and engaging with optional resources and (2) performance on the final exam.

The Student Experience

Student surveys were administered to students in fall 2014 and spring 2015. Survey questions comprised a mix of multiple-choice and open-ended questions. In fall 2014, 93 percent of enrolled students completed the survey, and in spring 2015, 94 percent of enrolled students completed the survey. Overall, students gave positive responses both semesters about their experience using Mastering Chemistry.

- For both fall and spring, 97 percent of respondents each semester said they were able to register and log on to Mastering Chemistry on their first attempt.
- Seventy-seven percent of respondents in the fall and 74 percent in the spring said that they would recommend Mastering Chemistry for courses in which it is available.

Student comments from the surveys included the following:

"Mastering Chemistry helped me to work through problems, especially the ones with hints, otherwise I might not have tried and just given up."

"I liked how we had one every week this semester instead of one for every chapter. This kept me on my feet and kept a sense of consistency and a routine in trying to retain information. The Adaptive Follow-Ups were also really good extra credit."

One open-ended question on the survey asked students what advice they would give to future students regarding how to best succeed in this course. Some answers included advice on doing the Mastering Chemistry homework:

"Do all the Mastering Chemistry homework and Adaptive Follow-Ups because they help you understand things you struggled on."

"Do it yourself before you Google answers; the practice really does help!"

"Do the Mastering Chemistry homework assignments and use the hints—they work!"

Conclusion

Crist says that Mastering Chemistry helps provide timely feedback to her students, as well as diagnostic data to inform her teaching and better construct homework assignments. In addition, she appreciates that it offers students help when they need it. Students in this study who engaged more with required Mastering Chemistry assignments and who scored higher on optional Mastering Chemistry assignments tended to do better on the final exam. Crist plans to continue using Mastering Chemistry and evaluating her results to track student learning in her course.

Implementation and results case studies share actual implementation practices and evaluate possible relationships between program implementation and student performance. The findings are not meant to imply causality or generalizability within or beyond these instances. Rather, they can begin to provide informed considerations for implementation and adaptation decisions in other user contexts. For this case study, mixed-methods designs were applied, and the data collected included qualitative data from interviews, quantitative program usage analytics, and performance data. Open-ended interviews were used to guide data collection.