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Technical Report

Study of Mastering Chemistry at selective research university

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Executive Summary

In the United States, General Chemistry is a required gateway course for most STEM majors in postsecondary degree programs. A growing number of instructors have adopted adaptive learning systems for homework and to support classroom instruction. As use of these systems becomes more widespread, it is important that we understand how they can be used to improve student learning, the benefits and challenges experienced by students and instructors, and whether use of these systems is associated with improvements in student outcomes. There is a lack of evidence available for technology-enhanced chemistry courses, particularly in higher education, and thus a pressing need for rigorous studies of adaptive learning products.

In order to advance this area of research, Pearson contracted with SRI Education, a non-profit research and development organization, to conduct an evaluation of Mastering Chemistry, an online homework, tutorial, and assessment system designed for use in postsecondary General Chemistry courses. To support independent study by students as well as classroom activities, the system includes personalized learning features to address students' individual needs. Assessments include quizzes and homework problems aligned with Pearson textbooks.

SRI conducted a study of Mastering Chemistry with a highly selective research university, referred to as Institution A, during fall term 2016 and winter term 2017 in General Chemistry I and General Chemistry II. (Another study of Mastering Chemistry was conducted with Ohio State University and is described in a separate report.) The present study examined the implementation of Mastering Chemistry at Institution A, including how the system was used in the course and the instructor and student experiences. In addition, we analyzed relationships between student usage of Mastering Chemistry and course outcomes, including final exam scores and course grades. We also examined costs of implementing the system compared to a prior version of the course that did not use an online supplement.

Data collections for the study included student surveys at the beginning and end of the fall term, an instructor survey, qualitative data from a site visit, course outcomes, usage data provided by Pearson, and cost data. Student and instructor surveys were conducted during fall 2016. The site visit to Institution A also took place during fall 2016 and involved interviews with the course coordinator, a partner instructor, a student focus group, and two class observations. For the cost analysis we collected information through the instructor survey, site visit, and phone interviews.

Two instructors participated in the study. The study population consisted of 407 students for the fall term and 360 students for the winter term. The final analytic samples for usage analysis included 345 students for the fall and 308 students for the winter term. For both terms we used hierarchical linear modeling to analyze relationships between the level of student use of Mastering Chemistry (specifically,

the number of attempted problems) and achievement outcomes. In addition, we explored whether there were interaction effects with background characteristics.

In order to address implementation related research questions, we analyzed data from surveys and site visits. Notes from the interviews and focus groups were reviewed for key themes across respondents. For the cost analysis, we took an "ingredients" approach, which identifies all inputs regardless of who bears the costs. Our analyses focused on costs of providing instruction, primarily staff time, as well as access costs for students.

Findings

Institution A offered General Chemistry I and II in the fall 2016 and winter 2017 terms respectively. The courses were intended primarily for students majoring in science or pre-med, though not chemistry majors. Both terms were taught in two large lecture sections of approximately 180-200 students each by two rotating instructors. In addition, the courses were supported by 12 Teaching Assistants (TAs).

Mastering Chemistry was an integral part of the course and was used mainly for homework assignments outside of class time. The instructors used Mastering Chemistry to "flip" the class by requiring students to cover materials before each lecture and using class time to solve problems related to this content. Mastering Chemistry was also used in an optional "outreach" course offered to students who felt they needed extra practice. Assignments were not individualized by student.

Primary benefits of Mastering Chemistry reported by instructors included: the time it saves TAs in grading homework, freed up class time that could be used for in-class problem solving, the ability to assign multiple problem sets each week, and alignment with the textbook and ability to customize the order of units. Both instructors and students thought students were more prepared for class due to use of the system.

Both instructors and students identified the requirement of particular inputs and formats for some problems as a challenge. Instructors also thought the solution key could be more useful. Additionally, instructors stated that in the past they felt Mastering Chemistry did not provide enough advanced problems but that this seemed to be improving. Students also expressed a desire for more advanced problems.

As the most valuable features, instructors cited Tutorial Problems, Interactive Worked Examples, and the ability to combine Mastering Chemistry powerpoint slides in the lecture with a worked example from the corresponding chapter. Neither of the instructors reported using the dashboard to review student responses to homework. Students rated wrong answer feedback as by far the most useful feature, followed by videos, hints, Dynamic Study Modules, and tutorial problems. Learning Catalytics

ranked lowest. Students generally gave very high ratings for the features that they reported using. Students reported finding Mastering Chemistry easy to use and encountering few technical problems.

Nearly half of students reported some degree of barriers to their use of Mastering Chemistry due to insufficient academic supports, including peer study groups, individual tutoring sessions, and group tutorial sessions/recitations. Students reported that they do not use Mastering Chemistry to review for tests, though they would if it were easier to do so.

When analyzing the association between usage of Mastering Chemistry and course outcomes, we found a statistically significant positive relationship between the number of problems attempted and two course outcome measures for both the fall and winter terms: final exam scores and course total score. These analyses controlled for students' self-reported background characteristics, including prior achievement (SAT/ACT), age and gender. In the fall term, each problem attempted was associated with a 0.196-point increase in the final exam score, which translates to a 1-point increase in the final exam score for every 5 problems attempted. Each problem attempted was also associated with a 0.338-point increase in the course total score, which translates to a 1-point increase in the final exam score for every 3 problems attempted. We did not find significant interaction effects between the number of problems attempted and self-reported prior achievement, age, or gender.

SRI did not identify material difference in costs for the version of the course that used Mastering Chemistry versus a prior version of the course that did not. The lack of difference is due in part to instructors' decision to redirect TA time savings from grading homework to other activities.

There are two primary limitations of this study. One is the lack of data for students who did not use Mastering Chemistry, without which we are unable to estimate the effects of product use on student outcomes. A second limitation is that in order to examine interaction effects we relied on self reported student background data, including prior achievement. The study can be strengthened by obtaining these two types of administrative data.

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Introduction

In the United States General Chemistry is a required gateway course for most STEM majors in postsecondary degree programs. A growing number of instructors have adopted adaptive learning systems as homework supplements and to support classroom instruction. As use of these systems becomes more widespread, it is important that we understand how these they can be used to support student learning, the benefits and challenges experienced by students and instructors, and whether use of these systems is associated with improvements in student outcomes. There is a lack of research available for technology-enhanced chemistry courses, particularly in higher education, and thus a pressing need for rigorous studies of adaptive learning products.

Prior research on adaptive software in chemistry is limited. Very few high quality studies been conducted in chemistry, especially in higher education settings. For example, out of seven high quality meta-analyses or meta-analytic reviews of adaptive learning technologies conducted in the last decade (Steenbergen-Hu and Cooper 2013, Steenbergen-Hu and Cooper 2014, Ma et al 2014, Kulik and Fletcher 2015, VanLehn 2011, Nesbit et al 2014, Durlach and Ray 2011), only around three articles out of over one hundred focused on chemistry. Out of these three (Mclaren and Isotani 2011, Mclaren et al 2011, Adamson et al 2014), only one focused on college-level students.

In order to advance this field of research, Pearson has contracted with SRI Education (https://www.sri.com/about/organization/education), a non-profit research and development organization in Menlo Park, CA, to conduct an evaluation of Mastering Chemistry, an adaptive learning system designed for use in postsecondary General Chemistry courses.

This is the final report on the study of implementation and usage of Mastering Chemistry in General Chemistry courses at a highly selective research university, referred to as Institution A. It includes results from data that SRI collected and analyzed for Fall term 2016 and winter term 2017, including surveys of students and instructors, qualitative data from a site visit, course outcomes, background information about students, use data provided by Pearson, and cost data.

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Description of Mastering Chemistry

Mastering Chemistry is an online homework, tutorial, and assessment system for postsecondary introductory General Chemistry courses. The system is designed to improve results and increase student engagement before, during, and after class. To support independent study by students as well as their classroom activities, it includes features that provide personalized learning that addresses students' individual needs. Assessments include quizzes and homework problems aligned with Pearson textbooks. Instructional supports include:

- hints, with targeted scaffolding for specific problems
- instructional videos
- wrong answer feedback
- Dynamic Study Modules, which help students study on their own by continuously assessing their activity and performance in real time and providing feedback
- Adaptive Follow-up Assignments, which are based on each student's past performance on coursework and which provide additional coaching and targeted practice as needed
- Learning Catalytics (LC), a tool for instructors to generate class discussion, customize lectures, and promote peer-to-peer learning using students' smartphones, tablets, or laptops to engage them in more interactive tasks and thinking.

Instructors have the option of using or disabling some features. They can also customize items in some features, such as Dynamic Study Modules, for better alignment with their own syllabi.

The Present Study

This report addresses the following primary research questions regarding Mastering Chemistry:

Implementation and experience

- What was the intended role of the product within the instructional system to support teaching and learning?
- What was the intended role of the instructors and what practices were used to integrate the product?
- To what extent were the products used as intended?
- What institutional, human, and technology factors facilitated or hindered product implementation?
- To what extent were instructors and students satisfied with their experience using the product and with the training and support provided?

Relationship between Mastering Chemistry usage, student characteristics, and student outcomes

- What are the relationships among incoming student proficiency, product use variables, and student outcomes?

Cost impact

- How does the use of Mastering Chemistry in General Chemistry courses affect the cost structure of the course?

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Methods

Sample Description

Table 1 shows the number of instructors and students associated with the fall 2016 and winter 2017 General Chemistry classes included in the study. Table 2 provides descriptive statistics for the student samples for fall 2016/winter 2017.

Table 1: Number of instructors and students in 2016-17 General Chemistry classes

Term	Instructors	Students
	Mastering Chemistry	Mastering Chemistry
Fall	2	407
Winter	2	360

Table 2: Characteristics of the student sample by term

Characteristic	Fall 2016 (N = 407)	Winter 2017 (N = 360)
Gender		
Male	147 (36.1%)	127 (35.3%)
Female	249 (61.2%)	225 (62.5%)
Age (Median)	19.0	19.0
Enrollment status		
Part-time	2 (0.5%)	1 (0.3%)
Full-time	364 (89.4%)	323 (89.7%)
Declared major (Yes)	77 (18.9%)	67 (18.6%)
Work status		
Not working	340 (83.5%)	305 (84.7%)
Part-time	32 (7.9%)	24 (6.7%)
Full-time	0 (0.0%)	0 (0.0%)

Parent college attendance (Yes)	323 (79.4%)	288 (80.0%)
English spoken as primary language in the home (Yes)	325 (79.9%)	289 (80.3%)

Note: Not all percentages add to 100% because some students did not reply to all questions. The majority of demographic variables were collected from the student survey, which was administered only in the fall term.

Analytical Samples for Usage Analysis

The final analytic sample used for usage analysis (the relationship between use and outcomes among users) is 390 for the fall term and 345 for the winter term. Merging of the data files for Institution A proceeded without issue. For the purposes of the usage analysis, SRI analysts were able to match more than 95% of students from the outcome data with students in the Pearson use files for both the fall term and the winter term. In the final analytic models, SRI further removed students with missing information on key variables. As a result, the analytic sample used for usage analysis is 345 for the fall and 308 for the winter term.

Appendix A provides detailed technical information regarding the data files, data cleaning, and data merging, including dataset linking issues.

Data Collections

Surveys

Student surveys. Student pre-surveys were distributed in the first week of fall term for all students. A student pre-survey was used to capture students' baseline attitudes toward chemistry, including their interest in the subject area and their beliefs about its relevance to their lives.[1] (Details on the specific statements are provided as a note under Figure 1 and subsequent figures. The distribution of students' baseline responses for each statement by institution are shown under Question 5 in Appendix B.)

Student post-surveys were distributed in the last week of classes during the fall 2016 term. The purpose was to explore students' use of features within the Mastering Chemistry system, usability, and benefits

[1] The two scales – Interest in Domain and Utility Value of Domain – were adapted from Hulleman, C. S., & Harackiewicz, J. M. (2009). Making education relevant: Increasing interest and performance in high school science classes. *Science, 326,* 1410-1412.

and challenges associated with Mastering Chemistry use. Student background information was collected in both the pre- and post-surveys.

Surveys were administered to all students 18 years or older in General Chemistry courses. The pre-survey and post-survey were administered in print using TeleForm by Cardiff Software, which allows completed surveys to be scanned with the survey data captured electronically. Appendices B and C provide frequency tables for the pre- and post-survey questions, respectively.

Instructor surveys. Instructor surveys, delivered online, were distributed three to five weeks before course completion in fall 2016 term.

Site Visits

SRI staff conducted site visits during fall 2016 to a sample of instructors and their students in the General Chemistry course. Site visits consisted of student focus groups, classroom observations, and in-person interviews with instructors. The visits/interviews were conducted three to five weeks before course completion. This was to enable capture of the experience of the students and instructors toward the end of the course, and to avoid interfering with finals week and finals preparation.

Student Outcome Data

SRI staff collected outcome data, including final exam score, final course score, and course letter grade for fall 2016 and winter 2017 terms. The final exam was a locally developed assessment with a combination of multiple choice, short answer and longer problems for which students can receive partial credit. The exam was developed by the two lead instructors, who calibrated level of difficulty based on student performance in previous years. Three teaching assistants (TAs) were assigned to "test run" the exam to ensure that timing, clarity, and content were appropriate.

System Use Log Files

SRI coordinated with Pearson data scientists to access backend data to monitor the use of the products and for information on product implementation. These data were obtained for fall 2016 and winter 2017 terms.

Analytic Approaches

Examination of implementation, practices, and student and instructor experience. Data from surveys and site visits were analyzed to understand how Mastering Chemistry was used, the facilitating factors and challenges associated with its use, and degree of student and instructor satisfaction with the courseware. To address these questions, descriptive statistics from survey data were supplemented with a narrative analysis of the qualitative data from instructor interviews and student focus groups.

Notes from the interviews and focus groups were reviewed for key themes that emerged across respondents.

Relationships among student factors, use of Mastering Chemistry, and student outcomes. We used linear regression models (hierarchical regression models when appropriate) to examine the relationship between the level of student use of Mastering Chemistry and course outcomes, controlling for students' baseline characteristics. The indicator of use examined was the number of unique problems each student attempted[2].

Cost analysis. SRI collected cost information through the instructor survey, site visit, and phone interviews. These data were entered into a template that captured possible cost impacts for setting up and delivering courses with Mastering Chemistry, both in the initial year and on an ongoing basis. We took an "ingredients" approach, which identifies all inputs regardless of who bears the costs. Our analyses primarily focused on costs of providing instruction, although we also considered differences in access costs for students. Costs of instructor time took into account the staffing mix (tenure-track faculty, nontenure-track faculty, and TAs) and factored in average total compensation for different types of staff. Total costs in each condition were divided by the number of students to calculate a cost per student.

[2] For example, if Jill attempted 10 unique problems and was correct on her first answer each time, then she would be counted as making 10 unique problem attempts. Similarly, if Jack attempted 10 unique problems yet took five attempts to reach the correct answer each time, he would also be counted as making 10 unique problem attempts. The reason for choosing to measure unique problem attempts is that this is a better measure of students' progress through the entire Mastering Chemistry curriculum than other potential attempt measures.

Results

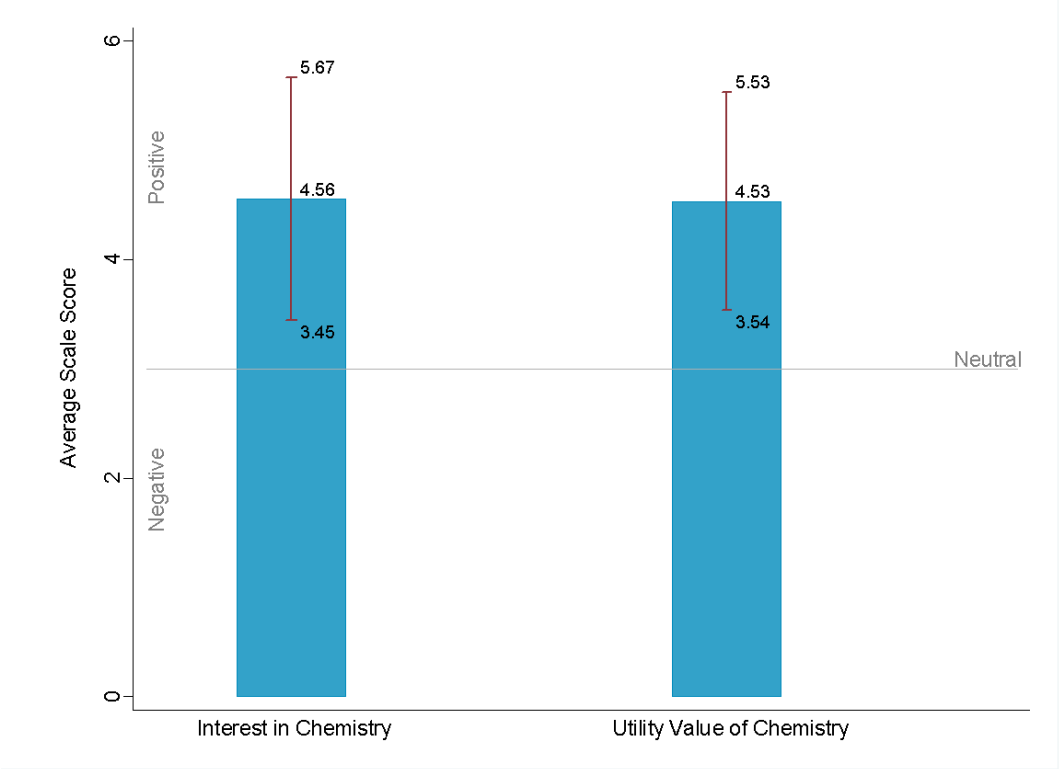
Implementation and Experience

These findings are based on site visit and survey data collected during fall 2016. While qualitative information about the course format and use of Mastering Chemistry apply specifically to the fall term, there were no significant changes in format or approach in the winter 2017 term, which is also included in this study.

Course overview

Institution A offered General Chemistry I and I primarily for students majoring in science or pre-med (including engineering and biology majors) in fall 2016 (Chemistry I) and winter 2017 (Chemistry II). Each course was 10 weeks long. The course was not aimed primarily at chemistry majors and served some students who scored relatively low on the AP Chemistry exam and whose high schools did not offer a chemistry course. As shown in Figure 1, the majority of students in the fall 2016 pre-survey reported positive baseline views about their interest in chemistry and their views on the utility of the subject.

Figure 1: Student interest in chemistry and their beliefs in its utility



Note: The Interest in Chemistry scale is a three-item scale based on data collected from the student pre-survey. Survey items were coded 0-6, running from "Not at all true" to "Very True" with "Neutral" coded as 3. Students were asked to report the extent to which the following statements described themselves in their chemistry class: "I think the field of chemistry is interesting." "To be honest, I just don't find chemistry interesting." "I think what we will be learning in class will be interesting." Similarly, the Utility Value of Chemistry scale is a three-item scale based on data collected from the student pre-survey. Survey items were coded 0-6, running from "Not at all true" to "Very True" with "Neutral" coded as 3. Students were asked to report the extent to which the following statements described themselves in their chemistry class: "I can apply what we are learning in chemistry class to real life." "I think what we are studying in chemistry class is useful to know." "I can see how what I learn from chemistry applies to life." The values shown on the graph represent (1) the mean value for the institution on the scale (value at the top of the bar), and (2) the values that correspond to plus and minus 1 standard deviation (SD) from the mean value.

Approximately 400 students enrolled in General Chemistry I in the fall 2016 term and 360 in General Chemistry II in the winter 2017 term (based on course outcomes data). Both terms were taught in two large lecture sections of approximately 180 to 200 students each by two instructors, who rotate by teaching unit.

The fall 2016 course was supported by 12 TAs, who taught sections of roughly 20 students each. Students attended class for three 50-minute sessions per week, plus a TA-led two-hour lab. Instructors taught using a mix of lecture and scaffolded problem-solving to demonstrate various principles, and one of the two instructors reports using more technology (including clickers) in the classroom. Instructors had office hours for approximately 90 minutes each a week, and TAs held approximately 15 hours of office hours per week. Similarly, General Chemistry II, offered in the winter term, was delivered in two large lecture sections. The course used the "Chemistry: A Molecular Approach" textbook by Nivaldo J. Tro. The lead instructor selected the text due to its aesthetic appeal, pedagogy, and "sort-plan-solve-check" strategy.

Students who need more support had the option to enroll in an additional one-credit "outreach" course that meets two hours per week. These students received additional opportunities for practice and review, primarily through the use of Mastering Chemistry. Approximately 25% of the class participated. Many of these students were encouraged to enroll by the instructors, though enrollment was optional.

Grades were based on a total possible score of 1000 points. Labs were worth up 120 points, midterms accounted for up to 360, and the final exam was worth up to 400 points. Students could receive up to 120 points for participation based on completion of Mastering Chemistry-based pre-lecture homework assignments and clicker questions in class (for the instructor who uses clickers).

Use Model

Mastering Chemistry was an integral part of the course and was used mainly for homework assignments. All use was outside of class time for practice and to introduce new concepts. Mastering Chemistry was used to facilitate a "flipped" instructional model. The instructors used Mastering Chemistry to help students prepare for each lecture by requiring students to read materials that would be covered in the next lecture and solve problems related to this content. Assignments were due the day before class and included problems related to content from the previous lecture plus problems related to content in the next lecture. Instructors also selected extra practice problems that tend to be more difficult than those in the core assignment and were not factored into students' grades. Mastering Chemistry was also used in the optional "outreach" course. These students received additional assignments in Mastering Chemistry.

Instructors set up Mastering Chemistry to allow multiple attempts at problems, although students were penalized each time they got a problem wrong. Students in focus groups reported that they disliked the penalty for wrong answers. Use of Hints was not penalized, to encourage students to use this feature. However, students received bonus points if they did not use Hints. Assignments were not individualized by student, and neither of the instructors reported using the dashboard to review student responses to homework.

The students actively used a Q&A platform, Piazza (https://piazza.com/), to facilitate peer-to-peer discussion around assigned Mastering Chemistry problems. A TA was assigned to review the discussion to verify the accuracy of student explanations and ensure that students were not spreading wrong answers or misconceptions. Some students reported being uncomfortable contributing to the Piazza discussion because the constant back and forth amongst students was overwhelming, or they were afraid of being judged by their peers. One instructor observed that there was more peer collaboration on problem sets prior to the adoption of Mastering Chemistry, when homework was paper-pencil problem sets. Students tended to work out solutions together and would come to office hours as a group and work through a problem orally with the instructor or TA. The instructor thought those practices may have led to deeper understanding. Roughly half of students reported in the survey that insufficient peer study groups had at least some impact on their Mastering Chemistry use (see Figure 6).

Benefits and Challenges of Mastering Chemistry Use

Instructor Perspective

A primary benefit of Mastering Chemistry for Institution A was the time it saves TAs in grading homework. The time previously spent grading was redirected to offer "interactive" labs. Lab write-ups included open-ended questions requiring extended written responses, which TAs have time to grade due to use of Mastering Chemistry.

Instructors reported that Mastering Chemistry enables problem sets to be split up into multiple assignments across the week, prompting students to come to class more prepared and freeing up time for more in-class problem solving. Students were assigned three problem sets per week, due the night before lecture, and this frequency of assignments would not be possible without Mastering Chemistry.

Another benefit of Mastering Chemistry was its alignment with the textbook and ability to customize the order of units. Instructors appreciated the ability to select problems by difficulty level and time it usually takes students to answer the problem. Other valuable features included the tutorial style problems, interactive worked examples, and ability to combine Mastering Chemistry PowerPoint slides in the lecture with a worked example from that chapter. Instructors would like to have some notifications or checks in place to avoid accidentally setting the wrong release time or date for the homework.

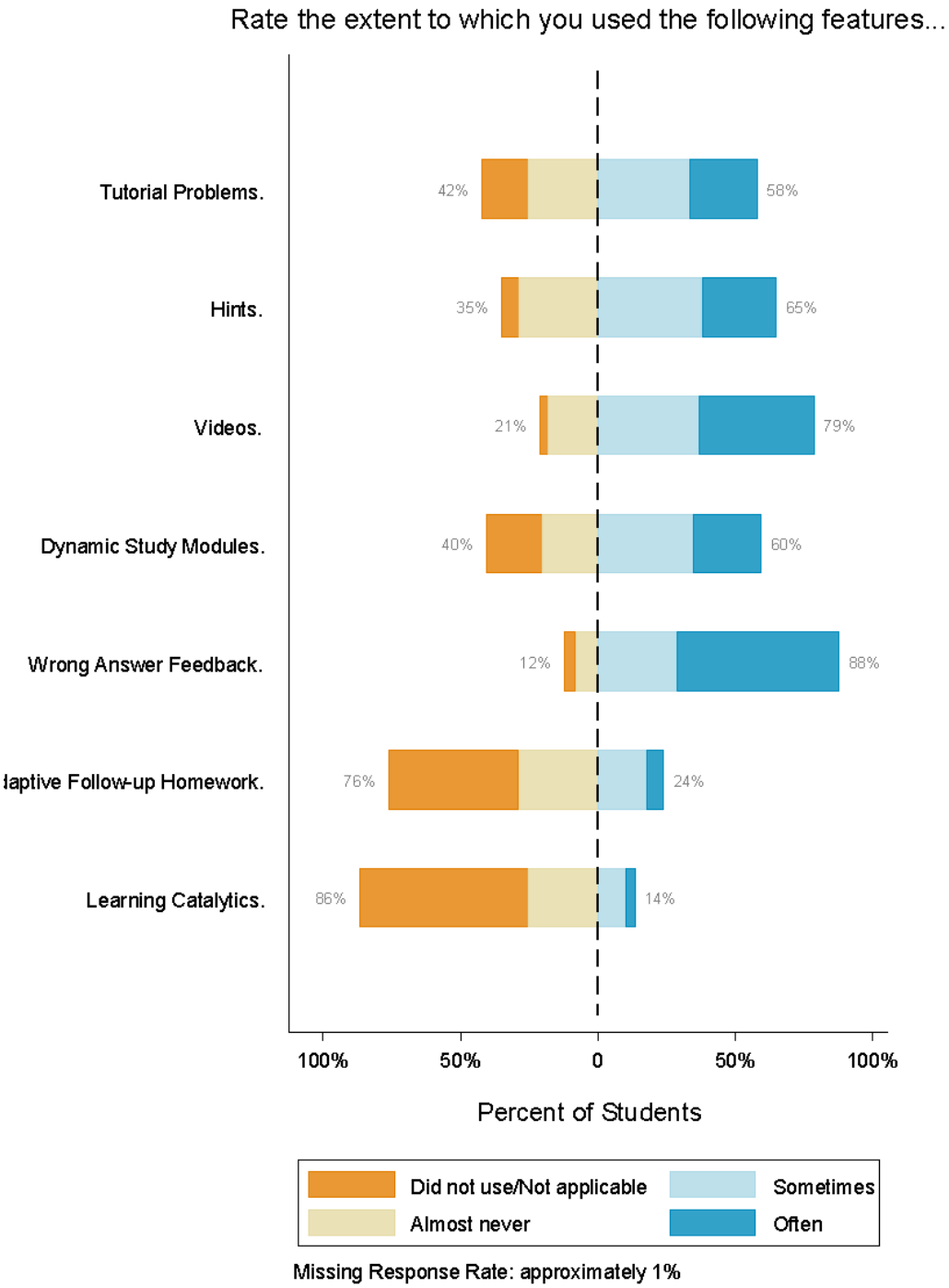
A challenge with Mastering Chemistry was that some problems require particular inputs and formats; a TA checked all problems before they were assigned to identify those that were "finicky." The TA took notes on these issues and communicated them to students so they knew how to input the problem correctly. Additionally, instructors stated that in the past they felt Mastering Chemistry did not provide enough advanced problems, but that this seems to be improving. Students expressed a desire for more advanced problems.

Instructors noted that the solution key for Mastering Chemistry is not useful. They found it difficult to understand the solution path and stated that there was no sense of logical thought process or concepts being applied. They would find it helpful for themselves and for the TAs to have a clearer solution guide integrated with Mastering Chemistry. In addition, they would like to be able to print problem set solutions in a cleaner format.

Student Perspective

As shown in Figure 2, in the fall 2016 post-survey, students rated wrong answer feedback as by far the most useful feature, with 88% of respondents saying they “often” or “sometimes” used this feature. Videos followed, with 79% of students reporting use of this feature, followed by hints, Dynamic Study Modules and tutorial problems. Learning Catalytics ranked lowest, with only 14% of students reporting significant use of this feature. (Adaptive Follow-up Homework and Learning Catalytics were not used by instructors, so students may have misinterpreted these features.) Several students reported in focus groups that they like the simulations, although they vary widely in quality.

Figure 2: Use of different Mastering Chemistry features

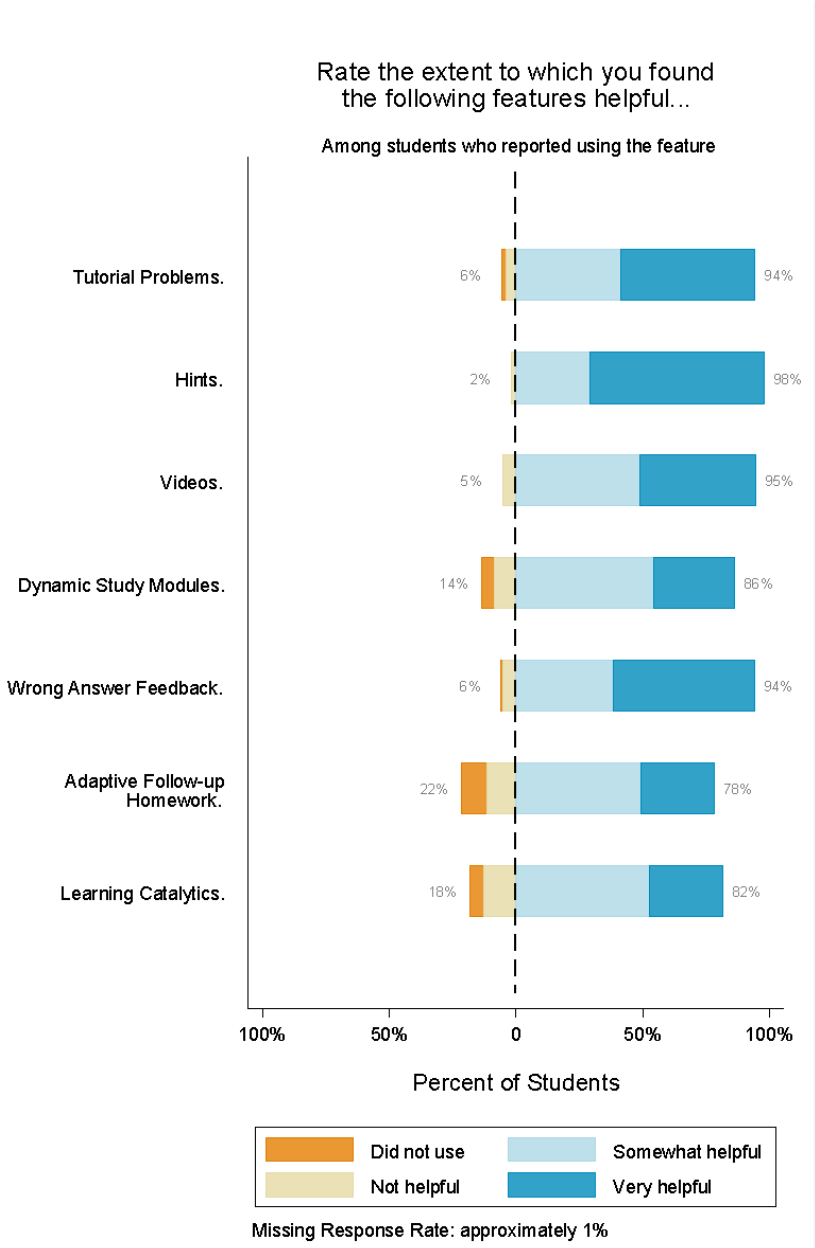


Missing Response Rate: approximately 1%

Note: The percentages shown to the left of 0% indicate not applicable, no, or less use of the features; the percentages to the right of 0% indicate greater use of the features.

As shown in Figure 3, in the post-survey students generally gave very high ratings for the features that they reported using. (Note that students were only asked to rate the helpfulness of features that they reported using, and again it is unlikely that they actually used Adaptive Follow-up Homework or Learning Analytics.) The top four most useful features were hints, tutorials, videos and wrong answer feedback. Dynamic Modules and Adaptive Follow-up Homework received slightly lower ratings of helpfulness, but even these were rated as “somewhat” or “very helpful” by over 70% of respondents.

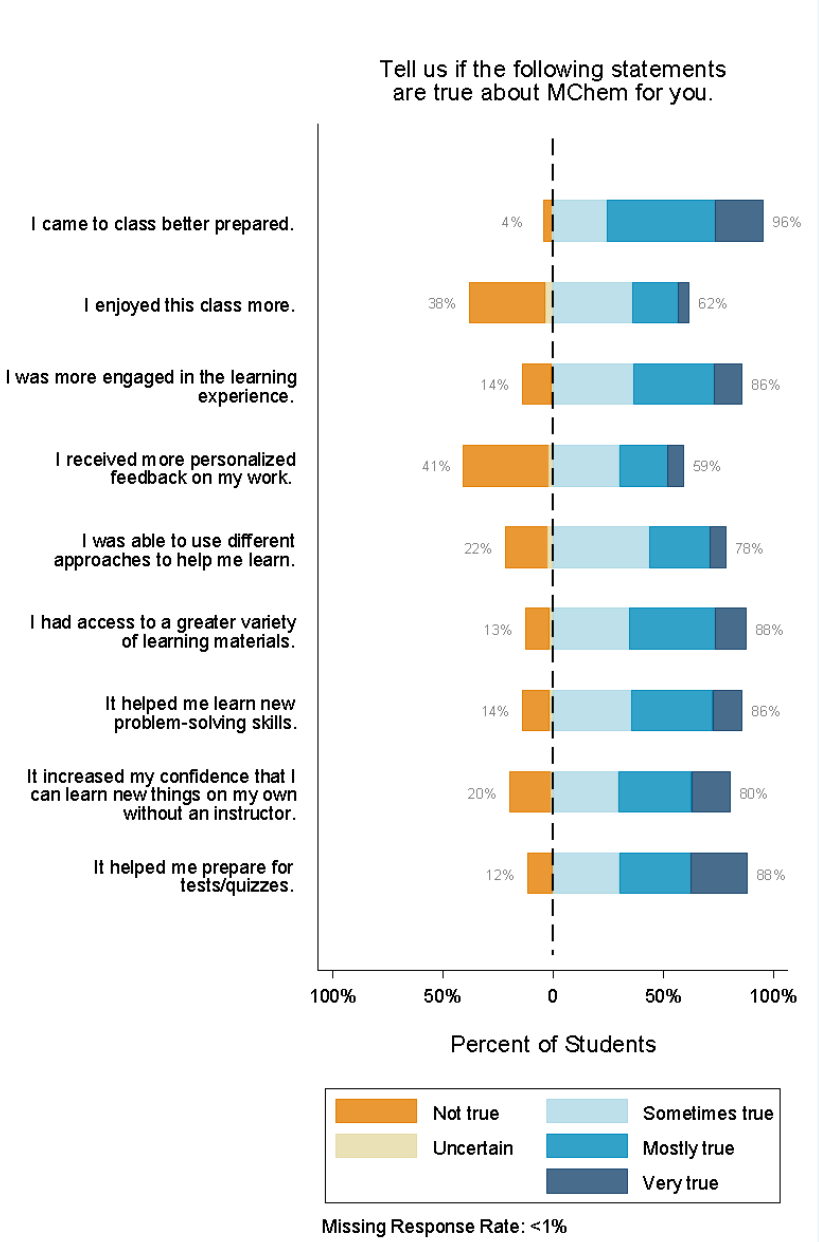
Figure 3: Students' self-reported experiences with Mastering Chemistry features



Note: The percentages shown to the left of 0% indicate the students did not use the feature or did not find the feature helpful; the percentages to the right of 0% indicate the feature was at least somewhat helpful.

In terms of the benefits of Mastering Chemistry, students were most likely to report in the post-survey that they felt better prepared. They were less likely to report that Mastering Chemistry enabled them to receive more personalized feedback and that it increased their enjoyment of the course, though over 50% of students still cited these as benefits (sometimes/mostly/very true), as shown in Figure 4.

Figure 4: Students' self-reported overall experiences with Mastering Chemistry

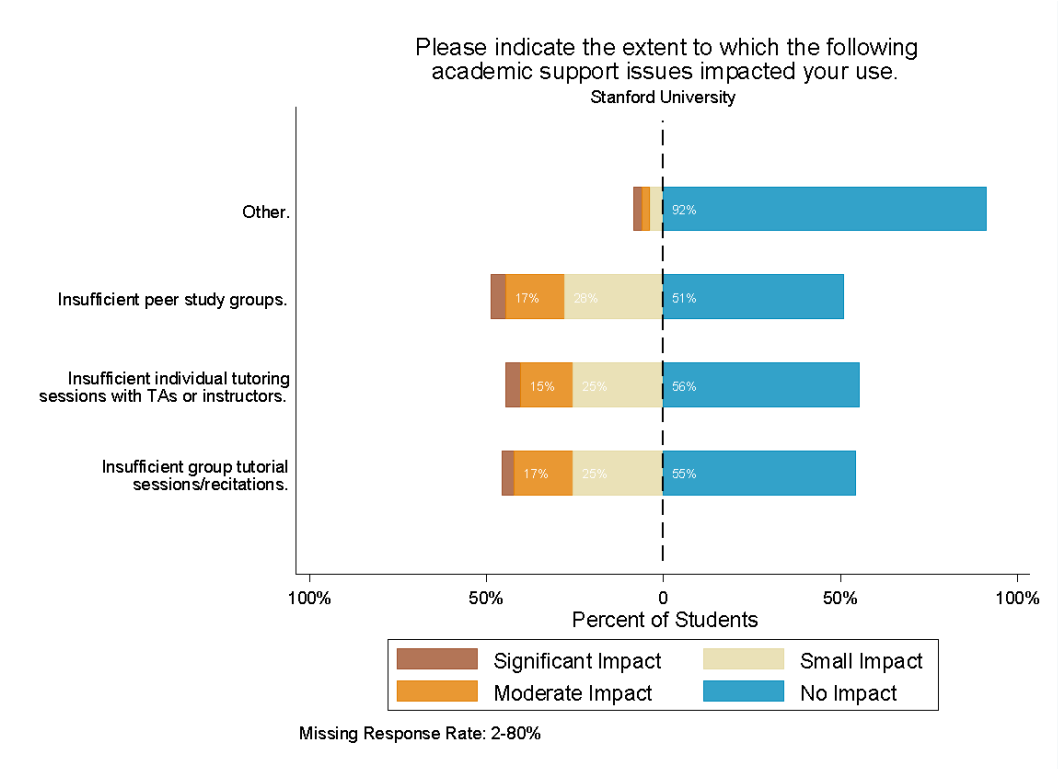


Note: The percentages shown to the left of 0% indicate that students were uncertain about how they felt about the statement of the potential benefit of Mastering Chemistry use or disagreed with the statement; the percentages to the right of 0% indicate that students agreed with the statement of the potential benefit of Mastering Chemistry use at least "sometimes".

In the post-survey, nearly half of students reported some degree of barriers to their use of Mastering Chemistry due to insufficient academic supports, as shown in Figure 5. Each of the specific academic supports addressed in the survey—peer study groups, individual tutoring sessions with TAs or

instructors, group tutorial sessions/recitations—were reported by between 44 and 49% of students to be insufficient to the point of affecting how they used Mastering Chemistry. Students reported that they do not use Mastering Chemistry to review for tests, though they would if it were easier to do so.

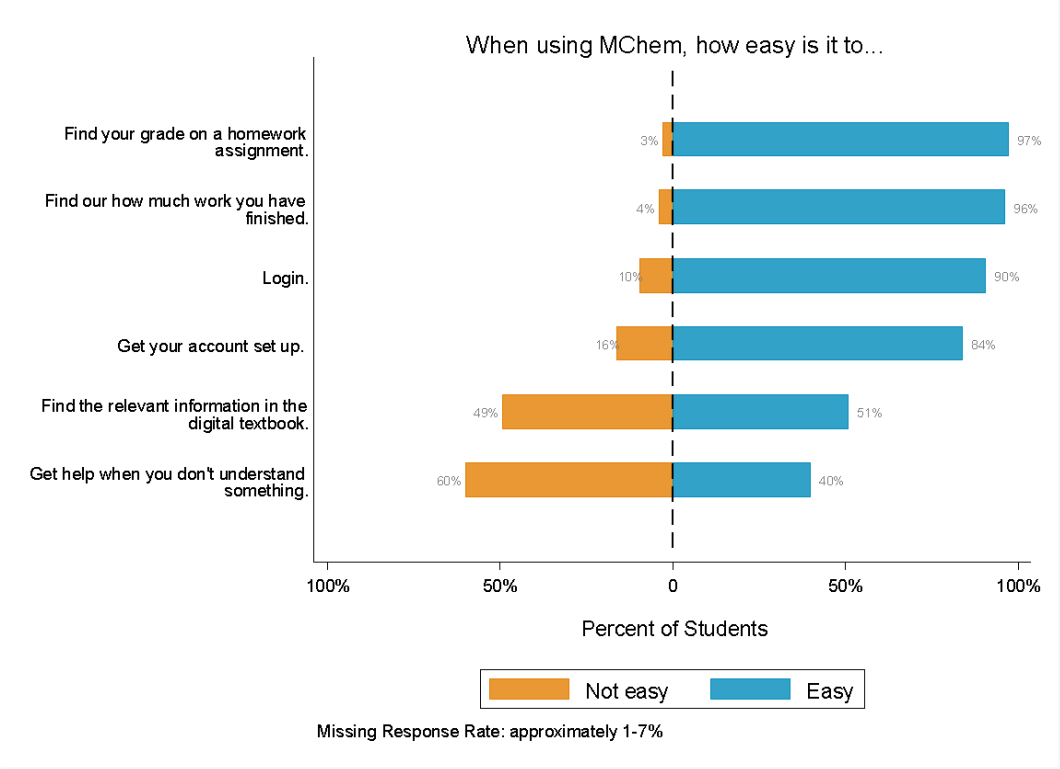
Figure 5: Barriers to use of Mastering Chemistry due to academic support issues



Note: The percentages shown to the left of 0% indicate that students found the factor to have some degree of impact on their use of Mastering Chemistry; the percentages to the right of 0% indicate that students found the factor to have no impact on their use of Mastering Chemistry.

Students reported finding Mastering Chemistry easy to use and encountering few technical problems (see Figure 6). Over 80% of students reported in the survey that logging in, finding how much work they completed, getting their account set up, and finding their grade on a homework assignment were easy to accomplish. The function with the lowest reported ease of use was "get help when you don't understand something," with 60% saying it was not easy. Both students and instructors commented on the long load times, especially for those with slow internet connections or cheaper laptops.

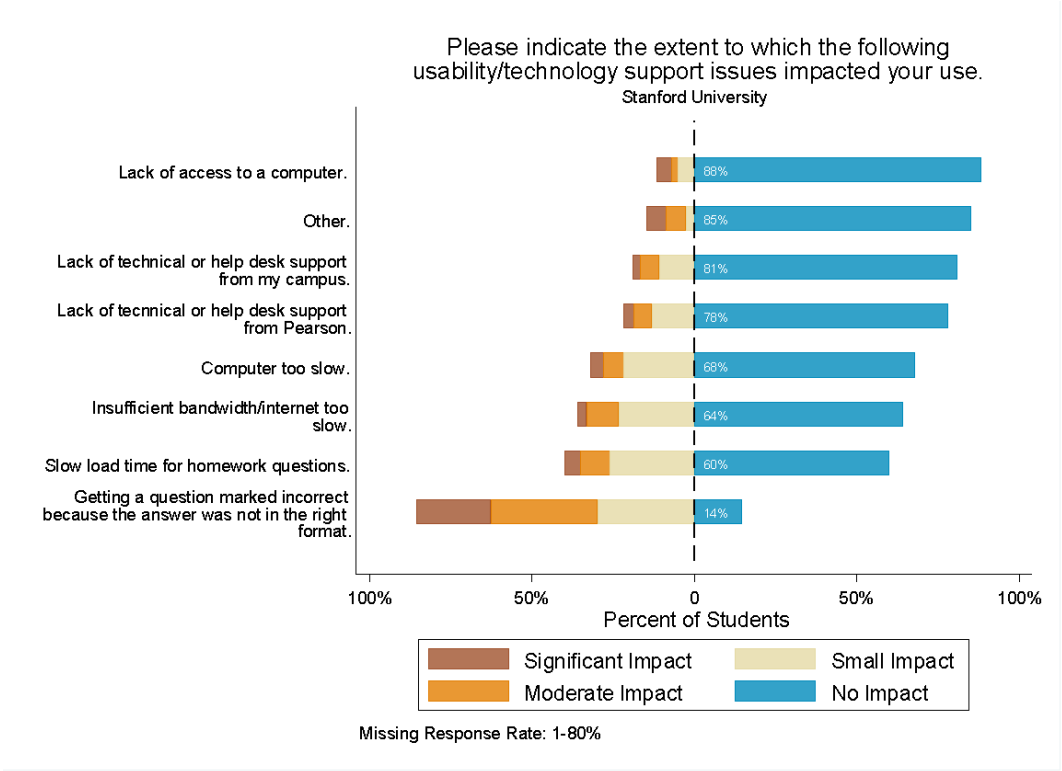
Figure 6: Ease of use of different Mastering Chemistry functions



Note: The percentages shown to the left of 0% indicate that students found that particular action not easy to complete; the percentages to the right of 0% indicate that students found that particular action easy to complete.

As shown in Figure 7, most students did not report negative impacts on how they used Mastering Chemistry for most of the specific issues asked in the survey. The exception is that 86% of students reported questions were marked as incorrect due to answers not being in the right format and that this negatively affected their use of Mastering Chemistry. To the extent that there were negative impacts due to other usability and technology support issues, the impacts were more often reported to be "small" rather than either "moderate" or "significant".

Figure 7: Effects of usability/technology issues on Mastering Chemistry use



Note: The percentages shown to the left of 0% indicate that students found the factor to have some degree of impact on their use of Mastering Chemistry; the percentages to the right of 0% indicate that students found the factor to have no impact on their use of Mastering Chemistry.

Examining the Relationship Between Use and Outcomes Per Term

The relationships between Mastering Chemistry use and two dependent variables were modeled using two multilevel models for the fall and winter terms. These models used outcome and usage data for the fall 2016 and winter 2017 terms respectively; however, the winter 2017 model used background covariates from the fall 2016 pre-survey. The dependent variables examined included *final exam scores* and *total course score*. We also collected grade outcome data and converted these to a *binary outcome* (whether students passed or not), but only a small number of students dropped or failed the course (less than 2% each term), resulting in a sample that was too small for use in estimating a reliable relationship. For a prior achievement covariate, we used students' self-reported ACT or SAT math scores from the student pre-survey[3]. When a student reported an SAT score, the score was converted to an

[3]There is evidence that self-reported student SAT scores are faily accurate, especially for students with higher grades and cognitive ability: Kuncel N. R., Credé M., Thomas L. L. (2005). The validity of self-reported grade point

ACT math score so that the prior achievement measures used in the models were comparable across institutions. If students reported multiple SAT scores, only the highest score was selected as a measure of their prior achievement level. Tables 3 and 4 report the results of the analyses.

We examined *number of problems attempted* as the usage indicator that best captures students' level of engagement with Mastering Chemistry. We also explored other usage indicators, such as aggregate raw score and total score, and found these indicators were very highly correlated with *number of problems attempted,* meaning that the relationships between these indicators and external course outcome measures is very similar.

Key Findings for Institution A

For the Institution A sample, we found a statistically significant positive relationship between the number of problems attempted and the two course outcome measures for both the fall and winter terms.

Main Effects. When the number of problems attempted was the use measure examined (Table 3 and Table 4) and controlling for student background characteristics, we found a statistically significant positive relationship between the number of problems attempted and the two course outcome measures—final exam score and total course score for the fall sample (B = +0.196 and +0.338) and winter sample (B = +0.180 and +0.397). The estimated B parameter represents the change in the outcome score for a one-unit change in the number of problems attempted. For example: in the fall term each problem attempted was associated with a 0.196-point increase in the final exam score, which translates to a 1-point increase in the final exam score for every five problems attempted. Each problem attempted was also associated with a 0.338-point increase in the course total score, which translates to a 1-point increase in the final exam score for every three problems attempted. Note that Mastering Chemistry assignment completion (120 out of 1000 points) was part of the total course score, so it was not a surprise to find that the coefficient was higher for predicting total course score than for predicting final exam score.

Interaction Effects. Interaction effects were examined for both the fall and winter data. Interaction terms were added to the model one by one, and removed if not found significant.

For both the fall sample and winter sample, with the dependent variable of final exam score and the dependent variable of total course score, no significant interaction effect was found between the number of problems attempted and prior achievement, age, or gender.

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averages, class ranks, and test scores: A meta-analysis and review of the literature. Review of Educational Research, 75(1), 63–82.

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Table 3: Fall 2016 HLM results for relationship between the number of problems attempted and Institution A student course outcome measures

Solution for Fixed Effects								
	Final Exam Scores				**Course Grades**			
Variable	***n***	**B**	***SE***	***p*-value**	***n***	**B**	***SE***	***p*-value**
Fixed effects	345				345			
Number of problems attempted		**0.196**	**0.038**	**< .0001**		**0.338**	**0.065**	**< .0001**
Prior achievement (ACT or SAT)		10.647	1.108	< .0001		19.726	1.878	< .0001
Age		-1.195	2.543	.6387		-4.100	4.313	.3425
Gender female		-1.062	5.525	.8477		-1.785	9.366	.8490
Gender other		31.960	27.676	.2490		40.535	46.895	.3880
Gender male		0.000	-	-		0.000	-	-
Random effects								
Level 1 intercept		-94.062	63.770	.1538		147.010	108.110	.1871
Level 2 intercept		119.36	77.731	.0623		285.400	205.340	.0823

Note: For final exam scores, the ICC was 2.01%, and the R-squared at the student level was 25.64%. For course grades, the ICC was 1.67%, and the R-squared at the student level was 28.95%. The time spent on Mastering Chemistry was in minutes. The final exam score was out of 400 points possible. The course grade was out of 1,000 points possible.

Note: The estimated B parameter represents the change in the outcome score for a one-unit change in the number of problems attempted, controlling for other independent variables in the model.

Table 4: Winter 2017 HLM results for relationship between the number of problems attempted and Institution A student course outcome measures

Solution for Fixed Effects								
	Final Exam Scores				**Course Grades**			
Variable	***n***	**B**	***SE***	***p*-value**	***n***	**B**	***SE***	***p*-value**
Fixed effects	308				308			
Intercept		-	-	-		113.597	128.166	.3761
Number of problems attempted		**0.180**	**0.054**	**.0011**		**0.397**	**0.097**	**< .0001**
Prior achievement (ACT or SAT)		11.444	1.270	< .0001		21.895	2.254	< .0001
Age		-1.992	2.960	.5016		-7.630	5.257	.1477
Gender female		5.808	6.333	.3598		13.764	11.229	.2212
Gender male		0.000	-	-		0.000	-	-
Random effects								
Level 1 intercept		-98.775	72.177	.1856		-	-	-
Level 2 intercept		8.810	61.968	.4435		-	-	-

Note: For final exam scores, the ICC was 1.66%, and the R-squared at the student level was 24.37%. For course grades, there was a convergence issue when hierarchical models were performed. Thus, a single-level model was performed instead. The time spent on Mastering Chemistry was in minutes. The final exam score was out of 400 points possible. The course grade was out of 1,000 points possible.

Note: The estimated B parameter represents the change in the outcome score for a one-unit change in the number of problems attempted, controlling for other independent variables in the model.

Cost Analysis

The primary cost driver associated with implementation of Mastering Chemistry was instructor and TA time, but overall we found that new time demands were offset by time savings. Initial time demands included review of Mastering Chemistry, customization of the system, and addressing technical issues. The lead instructor also spent significant time on professional development training related to Mastering Chemistry. Ongoing time demands include reviewing problems to assign in Mastering Chemistry and working with students to resolve registration issues. Time savings associated with Mastering Chemistry include not having to create homework problems from scratch.

TAs save substantial time grading homework, but this time saving has been redirected to other activities. These include reviewing problems and providing students with guidance on how solutions need to be formatted; offering an additional lab; and increased office hours.

Overall, SRI found no material difference in time required to teach General Chemistry using Mastering Chemistry versus without Mastering Chemistry. Therefore, we did not identify a difference in costs for delivering the course.

Table 5: Cost analysis

Cost Element	Value
Time difference per coordinator every 2 terms (hours)	3
Time difference per faculty every 2 terms (hours)	-3
# of instructors	2
Total cost difference in instructor time	$0
# students	838
Cost difference per student	**$0**

Note: cost calculations involve both instructors who taught Mastering Chemistry over the academic year. From the instructor survey, it was found that the product was used for five to six years. We assume 140 working days for nine months.

Limitations

There are two primary limitations of this study. One is the lack of data for students who did not use Mastering Chemistry, without which we are unable to estimate the effects of Mastering Chemistry use on student outcomes. A second limitation is that in order to examine interaction effects we relied on

self-reported student background data, including prior achievement. As noted earlier, while prior research has found that self-reported SAT/ACT scores are fairly accurate, especially for students with high cognitive ability, it is possible that some students did not report their scores accurately.

Discussion

Mastering Chemistry is used to assign, support and grade homework in General Chemistry courses at Institution A and to enable a more active instructional model. Students are given multiple assignments per week and expected to come to lecture prepared to do problem solving. A primary benefit of Mastering Chemistry is that students receive immediate feedback on problems. Additionally, TAs save substantial time grading homework, and this time can be redirected to other instructional activities, primarily an interactive lab.

Students rated wrong answer feedback as by far the most frequently used feature, followed by hints and videos. Students reported that Mastering Chemistry helps them come to class better prepared, have access to a greater variety of learning materials, and prepare for tests/quizzes. They were less likely to report that Mastering Chemistry enabled them to receive more personalized feedback or that it increased their enjoyment of the course.

The findings indicate a strong association between Mastering Chemistry use and improved course performance. When controlling for student prior achievement and demographic characteristics, the relationships between the number of problems attempted and two student course outcome measures (final exam score and total course scores) were statistically significant. We did not identify significant differences in the relationship between usage and outcomes for different types of students.

The primary cost driver is time for instructors and TAs to deliver the course. We did not find evidence that the costs to deliver the course with and without Mastering Chemistry differ materially.

Student outcome and demographic data for a comparison condition would be needed in order to estimate the impact of Mastering Chemistry use on student outcomes relative to an alternate version of the course, and to determine the relative cost effectiveness.

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References

Adamson, David, Gregory Dyke, Hyeju Jang, and Carolyn Penstein Rosé. 2014. "Towards an Agile Approach to Adapting Dynamic Collaboration Support to Student Needs." *International Journal of Artificial Intelligence in Education* 24 (1): 92–124. doi:10.1007/s40593-013-0012-6.

Durlach, Paula J, and Jessica M Ray. 2011. "Designing Adaptive Instructional Environments: Insights from Empirical Evidence (Technical Report 1297)." Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Kulik, James A, and J D Fletcher. 2015. "Effectiveness of Intelligent Tutoring Systems: A Meta-Analytic Review." *Review of Educational Research*, 1–37. doi:10.3102/0034654315581420.

Ma, Wenting, O. O. Adesope, J. C. Nesbit, and Qing Liu. 2014. "Intelligent Tutoring Systems and Learning Outcomes: A Meta-Analysis." *Journal of Educational Psychology* 106 (4): 901–18. doi:10.1037/a0037123.

McLaren, Bruce M., and Seiji Isotani. 2011. "When Is It Best to Learn with All Worked Examples?" In Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), edited by Gautam Biswas, Susan Bull, Judy Kay, and Antonija Mitrovic, 6738:222–29. Berlin Heidelberg: Srpinger. doi:10.1007/978-3-642-21869-9_30.

McLaren, Bruce M., Krista E. Deleeuw, and Richard E. Mayer. 2011. "Polite Web-Based Intelligent Tutors: Can They Improve Learning in Classrooms?" *Computers and Education* 56 (3): 574–84. doi:10.1016/j.compedu.2010.09.019.

Nesbit, John C., Olusola O. Adesope, Qing Liu, and Wenting Ma. 2014. "How Effective Are Intelligent Tutoring Systems in Computer Science Education?" In *2014 IEEE 14th International Conference on Advanced Learning Technologies*, 99–103. doi:10.1109/ICALT.2014.38.

Steenbergen-Hu, Saiying, and Harris Cooper. 2013. "A Meta-Analysis of the Effectiveness of Intelligent Tutoring Systems on K–12 Students' Mathematical Learning." *Journal of Educational Psychology* 105 (4): 970–87. doi:10.1037/a0032447

Steenbergen-Hu, Saiying, and Harris Cooper. "A meta-analysis of the effectiveness of intelligent tutoring systems on college students' academic learning." *Journal of Educational Psychology* 106.2 (2014): 331. Pecjak, Regan. "Q&A with Candace Thille, 'Adaptive Learning' Expert." *The Institution A Daily*, March 9, 2016. Issue 1479. http://www.theInstitution Adaily.com.

VanLehn, Kurt. 2011. "The Relative Effectiveness of Human Tutoring, Intelligent Tutoring Systems, and Other Tutoring Systems." Educational Psychologist 46 (4): 197–221. doi:10.1080/00461520.2011.611369.

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Appendix A: Data Management (Data Cleaning and Linking)

Data Files

To conduct the analyses, SRI analysts worked with 10 data files from 3 sources (see Table A1).

Table A1: Source and data files used in data analyses

SRI
Pre-student survey (fall)
Post-student survey (winter)
Teacher survey (winter)
Institutions of higher education
Institutional student linking file
Course outcome file
Pearson
Use data student linking file
Courseware use file
Assignment data file
Problems data file
Dynamic module data file

Data Cleaning

To prepare the data files for merging and analysis, there were two primary data-cleaning functions. First, analysts had to address duplicate records associated with the same student ID: these were dealt with on a case-by-case basis. Every attempt was made to distinguish which of the entries could be retained given the data provided, with the other entries deleted. Second, if students did not provide consent to participate in the study on either the student pre- or post-survey, or if they reported an age under 18, they were excluded from the sample. Table A2 shows the primary cleaning steps taken for the data files and the number of observations lost per cleaning step.

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Table A2: Data cleaning steps and number of records excluded from the analytical sample for each datafile and step

Data File	Initial N	Data Cleaning Step	Dropped N	Cleaned N
Pre-Survey	414	Duplicates	2	412
Post-Survey	413	No issues	0	413
Course Outcomes				
Fall Data	442	Unknown Student ID	35	407
Winter Data	396	Unknown Student ID	36	360
Mastering Chemistry Use				
Fall	456	No issues	0	456
Winter	405	No issues	0	405

Merging of Data Files

We first describe the overall logic and strategy for merging the various data files. We then discuss and present the results of file merging.

Overall Logic and Strategy for Merging

Impact analysis. To assemble the data file necessary for the impact analysis, we had to merge the course outcomes data file with at least one of the student survey data files (pre- or post-survey). The student demographic information used in the impact analysis was collected in those surveys.

To complete the merge, the Survey Student ID (SSID), assigned at the administration of the student pre-survey, served as the linking variable to connect the course outcome file provided by institution with the student survey data files. (Students needed to complete at least one survey to be included in the impact analysis.)

Use-Outcome Analysis. To assemble the data file necessary for the use versus outcome analysis, we followed the same process for merging the course outcome and survey files described above, and used a Student Linking File provided by the institution (student first and last name, and SSID) and a Use Linking File provided by Pearson (Product User ID and student first and last name) to merge the Pearson Use File with the outcome and survey data files. We used the two linking files to replace the

student identifier information in the use file (Product User ID and first and last name) with the SSID; doing so allowed us to merge the use file with the outcome and survey data files.

Table A3: Number of student records in each file type and number of student records merged

Institution A		
	Fall	**Winter**
Outcome data file	407	360
Use data files	456	405
Post-survey	413	413
Number of student records merged		
Outcome data file and post-survey	407	360
Outcome data file, use data file, and post-survey	390	345

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Appendix B: Pre-Survey Question Frequency Tables for Mastering Chemistry Users at Institution A (Treatment)

Q1. Have you taken an online course previously?

Reported in Percentages.

		N	Yes	No	No response
Institution A	Treatment	412	40.3	59.7	0.0

Q2. Have you ever used Mastering Chemistry before?

Reported in Percentages.

		N	Yes	No	No response
Institution A	Treatment	412	6.3	93.7	0.0

Q3. Have you ever used other Pearson learning products before?

Reported in Percentages.

		N	Yes	No	Not sure	No response

Institution A	Treatment	412	27.2	60.7	12.1	0.0

Q4a. I ask myself questions to make sure I know the material I have been studying.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.2	3.6	5.1	14.1	35	25	16	1

Q4b. When work is hard I either give up or study only the easy parts.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	31.8	43.4	14.3	5.6	2.4	1.2	0.7	0.5

Q4c. I work on practice exercises and answer end of chapter questions even when I don't have to.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response

Institution A	T	412	4.9	12.4	20.4	24.5	21.6	11.2	4.6	0.5

Q4d. I find that when the teacher is talking I think of other things and don't really listen to what is being said.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	14.6	37.4	26	13.8	4.9	1.9	0.7	0.7

Q4e. Even when study materials are dull and uninteresting, I keep working until I finish.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0	2.2	3.4	10.2	28.2	30.1	25.5	0.5

Q4f. Before I begin studying I think about the things I will need to do to learn.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	2.9	9.2	9.5	20.1	19.9	23.5	14.3	0.5

Q4g. I often find that I have been reading for class but don't know what it is all about.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	6.6	31.1	23.8	16.3	14.1	5.6	2.2	0.5

Q4h. When I'm reading I stop once in a while and go over what I have read.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	1	4.6	9.7	15.8	30.3	25.5	12.9	0.2

Q4i. I work hard to get a good grade even when I don't like a class.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0	1.2	0.2	1.9	10.4	27.9	58	0.2

Q5a. I think the field of chemistry is interesting.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.5	1.7	4.4	12.9	27.7	29.6	23.1	0.2

Q5b. I can apply what we are learning in chemistry class to real life.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.7	2.9	6.3	13.1	27.7	29.9	18.9	0.5

Q5c. I expect to do well in this class.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response

Institution A	T	412	0.7	2.9	6.1	19.9	28.4	27.4	13.8	0.7

Q5d. To be honest, I just don't find chemistry interesting.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	30.6	35.4	15.5	9.5	4.1	3.4	0.7	0.7

Q5e. I think what we will be studying in chemistry is useful to know.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.5	0.5	0.7	6.8	27.7	35.4	27.4	1

Q5f. Considering the difficulty of this course and my skills, I think I will do well in this class.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	1.5	2.4	9.7	24	26.7	26	9.2	0.5

Q5g. I think what we're learning in this class will be interesting.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.5	1.2	1.9	11.2	31.6	32.3	21.1	0.2

Q5h. I can see how what I learn from chemistry applies to life.

Reported in Percentages.

		N	Not at all true	Mostly untrue	Somewhat untrue	Neither true or untrue	Somewhat true	Mostly true	Very true	No response
Institution A	T	412	0.2	1.9	5.6	9.7	27.7	30.3	24	0.5

Q6a. You have a certain amount of intelligence and you really can't do much to change it.

Reported in Percentages.

		N	Strongly agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly disagree	No response
Institution A	T	412	1	2.7	9.5	23.8	30.8	31.6	0.7

Q6b. You can learn new things, but you can't really change your basic intelligence.

Reported in Percentages.

		N	Strongly agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly disagree	No response
Institution A	T	412	1.2	3.2	17	29.6	28.9	19.2	1

Q6c. Your intelligence is something about you that you can't change very much.

Reported in Percentages.

		N	Strongly agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly disagree	No response
Institution A	T	412	1	2.7	10	23.5	34.7	27.4	0.7

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Appendix C: Post-Survey Question Frequency Tables for Mastering Chemistry Users (Treatment)

Q1. How often on average did you use Mastering Chemistry to help you learn chemistry?

Reported in Percentages.

		N	Daily or almost every day	2-3 times each week	One time per week	One time every 2-3 weeks or less	Never	[missing]
Institution A	T	413	21.8	76	1	0.5	0.2	0.5

Q3. When do you primarily use Mastering Chemistry for this course?

Reported in Percentages.

		N	In class, during regular class time	In computer lab, as part of scheduled lab time	Outside of regularly scheduled class or lab time	no response
Institution A	T	413	0	0	99	1

Q4a. How easy is it to get your account set up? *Reported in Percentages.*					
		N	Easy	Not easy	no response
Institution A	T	413	83.1	16	1

Q4b. How easy is it to login? *Reported in Percentages.*					
		N	Easy	Not easy	no response
Institution A	T	413	89.8	9.4	0.7

Q4c. How easy is it to find your grade on a homework assignment? *Reported in Percentages.*					
		N	Easy	Not easy	no response
Institution A	T	413	96.6	2.9	0.5

Q4d. How easy is it to find the relevant information in the digital textbook? / How easy is it to find information you are looking for?

Reported in Percentages.

		N	Easy	Not easy	no response
Institution A	T	413	47.5	46	6.5

Q4e. How easy is it to get help when you don't understand something?

Reported in Percentages.

		N	Easy	Not easy	no response
Institution A	T	413	39	58.6	2.4

Q4f. How easy is it to find out how much work you have finished?

Reported in Percentages.

		N	Easy	Not easy	no response
Institution A	T	413	95.4	3.9	0.7

Q5a. When using Mastering Chemistry, I believe I came to class better prepared.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	21.8	48.4	24.5	3.9	0.5	1

Q5b. When using Mastering Chemistry, I believe I enjoyed this class more.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response

Institution A	T	413	5.3	20.3	35.8	34.4	3.4	0.7

Q5c. When using Mastering Chemistry, I believe I was more engaged in the learning experience.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	12.3	36.6	36.1	13.3	0.7	1

Q5d. When using Mastering Chemistry, I believe I received more personalized feedback on my work.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	7.3	21.5	29.8	38.5	1.7	1.2

Q5e. When using Mastering Chemistry, I believe I was able to use different approaches to help me learn.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	7	27.4	43.1	18.9	2.4	1.2

Q5f. When using Mastering Chemistry, I believe I had access to a greater variety of learning materials.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	13.6	38.7	34.1	10.9	1.5	1.2

Q5g. When using Mastering Chemistry, I believe it helped me learn new problem-solving skills.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	13.6	36.3	35.4	12.3	1.5	1

Q5h. When using Mastering Chemistry, I believe it increased my confidence that I can learn new things on my own without an instructor.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	17.2	33.2	29.3	18.6	1	0.7

Q5i. When using Mastering Chemistry, I believe it helped me prepare for tests and quizzes.

Reported in Percentages.

		N	Very true	Mostly true	Sometimes true	Not at all true	Not sure / uncertain	no response
Institution A	T	413	25.4	32.2	30	11.6	0	0.7

Q6a. I think the field of chemistry is interesting.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	2.4	3.9	8.2	15.7	27.4	25.9	15.7	0.7

Q6b. I can apply what we are learning in chemistry class to real life.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	1.7	6.5	11.4	16.5	29.1	22.3	11.9	0.7

Q6c. To be honest, I just don't find chemistry interesting.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	23	30	16.9	11.6	5.3	9.2	3.1	0.7

Q6d. I think what we are studying in chemistry is useful to know.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	1.9	4.6	6.3	16.7	28.3	25.4	15.5	1.2

Q6e. I think what we're learning in this class is interesting.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	1.5	4.1	10.4	14.8	31	22.8	14.3	1.2

Q6f. I can see how what I learn from chemistry applies to life.

Reported in Percentages.

		N	Not at all true of me	Mostly untrue	Somewhat untrue	Neutral	Somewhat true	Mostly true	Very true of me	no response
Institution A	T	413	1.5	2.7	9.4	17.4	28.1	24	16	1

Q7a. You have a certain amount of intelligence and you really can't do much to change it.

Reported in Percentages.

		N	Strongly Agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly Disagree	no response

Institution A	T	413	0.7	4.6	11.6	28.8	30.8	22.3	1.2

Q7b. You can learn new things, but you can't really change your basic intelligence.

Reported in Percentages.

		N	Strongly Agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly Disagree	no response
Institution A	T	413	1.7	7.3	16	30.8	25.9	17.4	1

Q7c. Your intelligence is something about you that you can't change very much.

Reported in Percentages.

		N	Strongly Agree	Agree	Mostly agree	Mostly disagree	Disagree	Strongly Disagree	no response
Institution A	T	413	1	4.6	11.1	26.6	33.4	22	1.2

Q8a. Insufficient group tutorial sessions/recitations impacted my use of Mastering Chemistry. / Insufficient tutorial sessions impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	3.4	16.2	24.9	53.5	1.9

Q8b. Insufficient individual tutoring sessions with TAs or instructors impacted my use of Mastering Chemistry. / Insufficient extra tutoring availability impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	4.1	14.5	24.9	54.5	1.9

Q8c. Insufficient peer study groups impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	4.1	16.5	27.4	50.4	1.7

Q8d. Other reasons impacted my use of Mastering Chemistry. *Reported in Percentages.*							
		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	0.5	0.5	0.7	18.4	79.9

Q9a. Lack of access to a computer impacted my use of Mastering Chemistry. / Insufficient computers impacted my use of Mastering Chemistry. *Reported in Percentages.*							
		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	4.4	2.2	4.8	87.2	1.5

Q9b. Too slow computer impacted my use of Mastering Chemistry. *Reported in Percentages.*							
		N	Significant impact	Moderate Impact	Small Impact	No impact	no response

Institution A	T	413	3.9	6.3	21.3	67.3	1.2

Q9c. Insufficient bandwidth/too slow internet impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	2.7	9.7	23	63.4	1.2

Q9d. Slow load time for homework questions impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	4.6	9	25.4	59.1	1.9

Q9e. Getting a question marked incorrect because incorrectly formatted impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	22.8	32.2	29.3	14.3	1.5

Q9f. Lack of technical or help desk support from my campus impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	2.18	5.81	10.65	79.9	1.45

Q9g. Lack of technical or help desk support from Pearson impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	2.91	5.57	12.83	77.24	1.45

Q9h. Other reasons impacted my use of Mastering Chemistry.

Reported in Percentages.

		N	Significant impact	Moderate Impact	Small Impact	No impact	no response
Institution A	T	413	1.21	1.21	0.48	16.71	80.39

Q10a. How often did you use Tutorial Problems?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	24	33.2	24.7	16.7	1.5

Q10b. How often did you use hints?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	26.6	37.8	28.3	6.3	1

Q10c. How often did you use videos?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	41.2	36.6	17.9	2.9	1.5

Q10d. How often did you use Dynamic Study Modules?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	24.2	34.1	19.9	19.9	1.9

Q10e. How often did you use wrong answer feedback?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response

Institution A	T	413	58.4	28.6	8	4.1	1

Q10f. How often did you use Adaptive Follow-up Homework?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	5.8	17.9	28.6	46.5	1.2

Q10g. How often did you use Learning Catalytics?

Reported in Percentages.

		N	Often	Sometimes	Almost Never	Did Not Use / Not Available	no response
Institution A	T	413	3.1	10.2	24.7	60.3	1.7

Q11a. How helpful was the Tutorial Problems aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	34.4	40.2	6.5	17.7	1.2

Q11b. How helpful was the hints aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	52.1	35.1	5.6	6.5	0.7

Q11c. How helpful was the videos aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	37.5	47.7	10.9	2.7	1.2

Pearson

Q11d. How helpful was the Dynamic Study Modules aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	18.9	39.2	12.6	27.8	1.5

Q11e. How helpful was the wrong answer feedback aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	49.9	37.3	7	4.8	1

Q11f. How helpful was the Adaptive Follow-up Homework aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response

Institution A	T	413	8.5	22.3	12.8	54.7	1.7

Q11g. How helpful was the Learning Catalytics aspect?

Reported in Percentages.

		N	Very Helpful	Somewhat Helpful	Not Helpful	Did Not Use	no response
Institution A	T	413	5.3	16	11.6	65.4	1.7

Q13. Would you prefer your instructor made more or less use of Mastering Chemistry in this class?

Reported in Percentages.

		N	More Use	Less Use	Don't change; it's about right	no response
Institution A	T	413	6.8	28.8	62.7	1.7

Q15. Do you intend to continue taking chemistry courses in the future?

Reported in Percentages.						
		N	Yes	No	Not Sure	no response
Institution A	T	413	85.7	3.6	8	2.7

Appendix D. Use Descriptives

Descriptive Statistics on Use

In analyzing the fall and winter use data, SRI focused on data related to assignments and problem attempts. Pearson distinguishes activity by assignment type—homework, extra practice, test, and adaptive. However, instructors can also create their own assignment types. Therefore to ensure consistency across institutions, SRI regrouped assignment types with guidance from Pearson staff. Table D1 shows how assignment types were grouped for this analysis. Tables D2 and D3 provide descriptive statistics for Mastering Chemistry assignment types and use variables for the fall and winter terms, respectively. Figures D1 through D4 provide Mastering Chemistry use statistics for the fall and winter terms.

Table D1: Reassignment of assignment types in Mastering Chemistry use data

Pearson Group Suggestion	Assignment Types	SRI Label
Group 1	Homework	Homework
Group 2	Extra Practice	Extra Practice

Pearson

Table D2: Descriptive statistics for Mastering Chemistry use variables based on student-level system data for the fall term

Institution A						
Variable	***n***	**Mean**	**SD**	**Min**	**Median**	**Max**
Overall						
Unique Days	390	34.14	6.10	3.00	34.00	54.00
Percentage of Class Days Used	390	49%	9%	4%	49%	77%
Time Spent on Mastering Chemistry (hours)	390	29.52	8.07	2.72	28.80	58.51
Unique Assignments	390	30.04	5.12	3.00	30.00	41.00
Unique Problems	390	268.79	69.12	23.00	250.00	545.00
Homework						
Time Spent on Mastering Chemistry (hours)	390	25.80	6.31	2.47	25.71	46.26
Number of Assignments	390	25.08	2.40	3.00	25.00	27.00
Number of Problems	390	217.43	23.80	21.00	219.00	259.00
Extra Practice						
Time Spent on Mastering Chemistry (hours)	390	3.7	4.5	0.0	1.9	23.6
Number of Assignments	390	51.4	57.9	0.0	31.5	309.0
Number of Problems	390	5.0	3.9	0.0	4.0	14.0
Wrong Attempts per Problem	390	0.90	0.36	0.15	0.84	2.39
Hints per Problem	390	0.32	0.30	0.00	0.25	1.95
Points per Problem	390	0.87	0.12	0.52	0.91	1.01
Raw Score per Problem	390	0.96	0.04	0.75	0.97	1.02
Score per Problem	390	0.92	0.06	0.65	0.93	1.01
% of Assigned Credits Finished	390	96%	4%	66%	97%	1%

Pearson

Table D3: Descriptive Statistics for Mastering Chemistry use variables based on student-level system data for the winter term

Institution A						
Variable	***n***	**Mean**	**SD**	**Min**	**Median**	**Max**
Overall						
Unique Days	345	30.38	5.53	2	30	47
Percentage of Class Days Used	345	43%	8%	3%	43%	67%
Time Spent on Mastering Chemistry (hours)	345	25.86	7.15	1.80	24.85	48.36
Unique Assignments	345	27.53	5.94	3	25	43
Unique Problems	345	232.93	55.95	11	215	429
Homework						
Time Spent on Mastering Chemistry (hours)	345	25.65	6.97	1.80	24.81	47.32
Number of Assignments	345	26.75	4.91	3	25	39
Number of Problems	345	227.77	48.46	11	214	398
Extra Practice						
Time Spent on Mastering Chemistry (hours)	345	0.21	0.41	0	0	2.59
Number of Assignments	345	5.17	9.62	0	0	36
Number of Problems	345	0.78	1.31	0	0	4
Wrong Attempts per Problem	345	0.93	0.37	0.18	0.87	2.19
Hints per Problem	345	0.41	0.37	0.00	0.33	1.93
Points per Problem	345	0.83	0.12	0.50	0.89	1.00
Raw Score per Problem	345	0.94	0.05	0.74	0.95	1.02
Score per Problem	345	0.92	0.06	0.68	0.93	1.02
% of Assigned Credits Finished	345	0.97	0.05	0.47	0.99	1.00

Figure D1: Distribution of time spent on Mastering Chemistry by student for the fall term

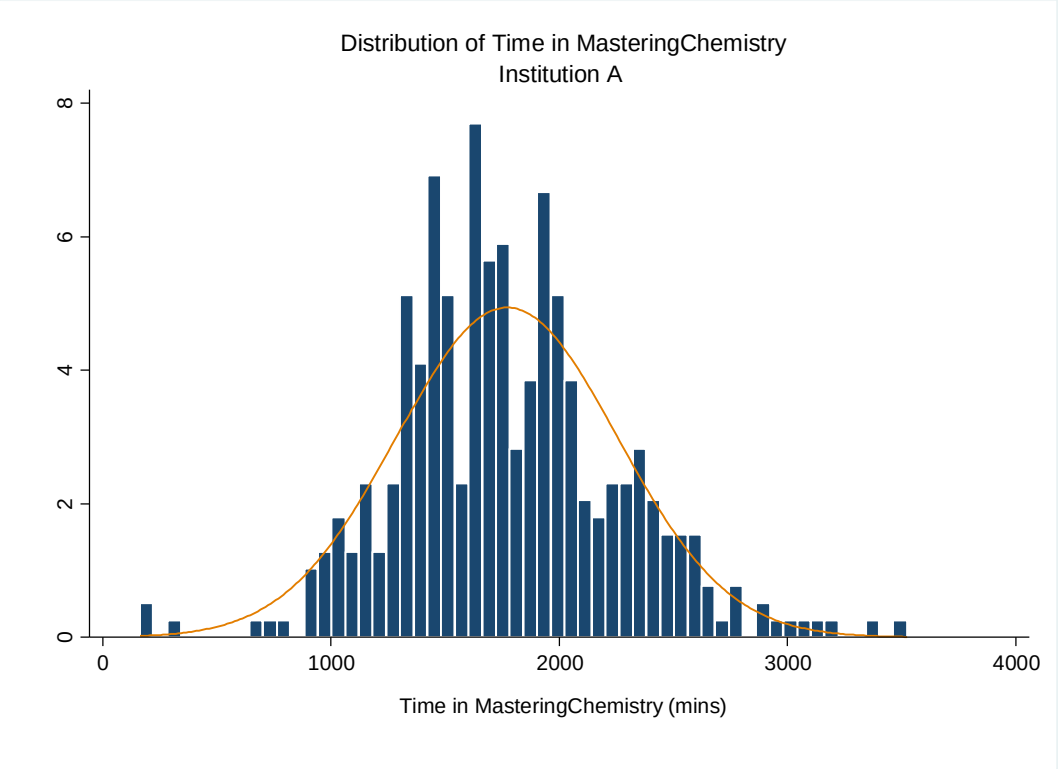


Figure D2: Distribution of number of problems attempted in Mastering Chemistry for the fall term

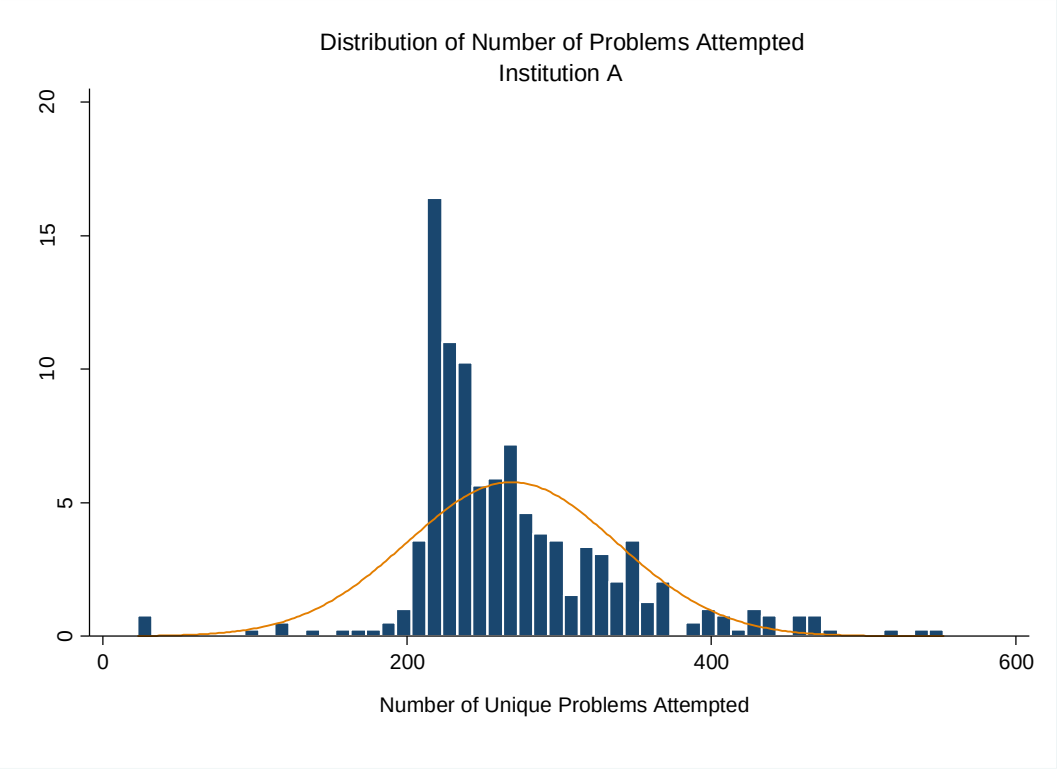


Figure D3: Distribution of time spent on Mastering Chemistry by student for the winter term

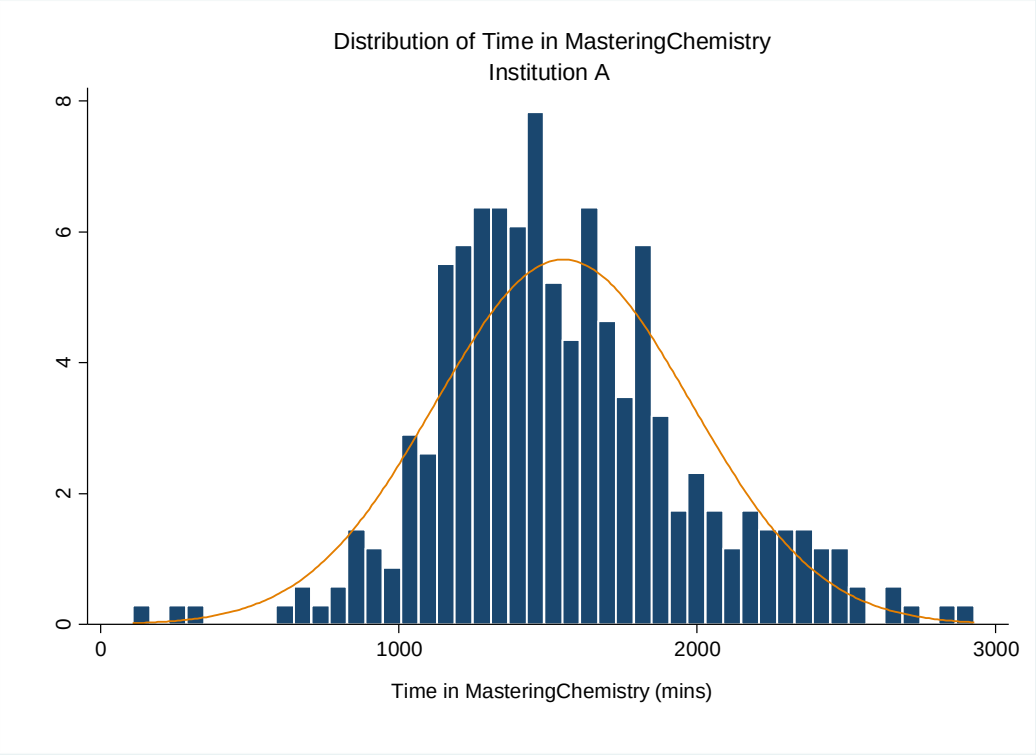
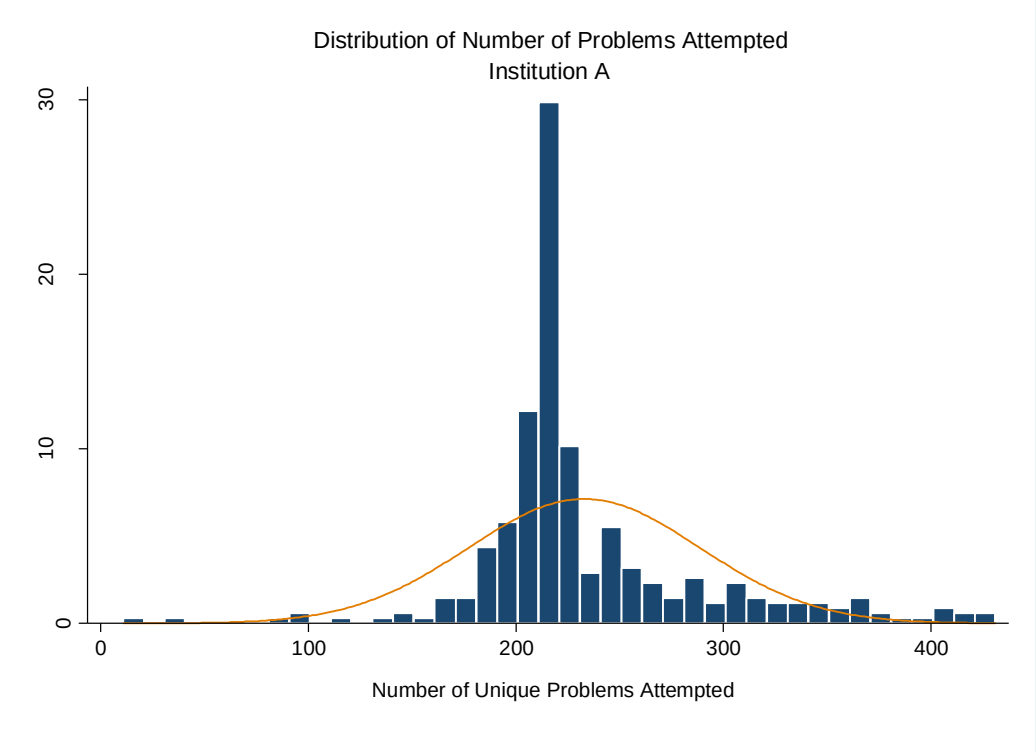


Figure D4: Distribution of number of problems attempted in Mastering Chemistry for the winter term



Appendix E. Teacher Characteristics Descriptives, Fall Chem I

	Teacher A	Teacher B
Condition	Treatment	Treatment
Product	Mastering Chemistry	Mastering Chemistry
Number of sections taught	24	24
Years' experience with product	3-4	5-6
Years teaching college courses	28	9
Years teaching at Institution A	28	9
Position at Institution A	Tenured faculty member	Full-time lecturer