Pearson

Mastering Chemistry

Efficacy Research Report

April 3 2018

Contents

The corpus of research for this product includes research conducted by our in-house researchers in partnership with customers, and research conducted by third party researchers. All research included in this report meets the standards we have set out for our own efficacy research. These are informed by and aligned with guidance on educational research quality provided by organisations, such as the American Educational Research Association and the What Works Clearinghouse.

Efficacy statements in this report are subject to independent assurance by PricewaterhouseCoopers LLP (PwC). The PwC assurance report is on page 24 and further details can be found in the Pearson Efficacy Reporting Framework dated April 3 2018.

Introduction

In 2013, Pearson made a commitment to efficacy: to identify the outcomes that matter most to students and educators, and to have a greater impact on improving them. Our aspiration is to put learners at the heart of the Pearson strategy; our goal, to help more learners, learn more. Part of our commitment was to publish research regarding the impact of the use of our products on outcomes, and to have the outcomes subject to independent audit. We call this efficacy reporting. There is no rulebook for how to do this, no model to follow. We've had to learn fast during this journey, we've sought guidance from others including external expertise, and we are now some, but not yet all of the way there.

The road taken and the milestone reached

In a first for the education sector, we have published audited efficacy reports on some of our most widely used products. Together, these products represent 18 million learners. This Research Report includes independently audited efficacy statements that have been prepared using the Pearson Efficacy Reporting Framework dated April 3 2018 — which we have used consistently for the Pearson products we are reporting on.

We have sought to use the efficacy reporting process to amplify existing non-Pearson peer reviewed research about our products. We've also sought to foster innovation in efficacy research by conducting new research and placing value on a range of research methods — including implementation studies, correlational and causal designs — ensuring data is collected, analyzed and presented to agreed standards at the appropriate stages in each product's lifecycle. The research conducted for this report, and the efficacy statements produced as a result, are designed based on international best practices such as those set out by the American Education Research Association and the What Works Clearinghouse. We have synthesized these into a set of standards we hold ourselves accountable for in our research and reporting. These are set out in the Pearson Efficacy Reporting Framework dated April 3 2018.

Furthermore, we adhere to the same peer-review processes as other high quality research in the education sector. Our work was independently reviewed and validated by SRI International, a well-known non-profit research center, and shared for discussion at research conferences organized by, among others, the American Education Research Association.

Our body of research contains evidence of statistically significant relationships between the use of our products and learner outcomes like student achievement. We want to be clear, though, that efficacy is not a quality a digital product can possess in and of itself. We recognize that implementation — the way a product is integrated into teaching and learning — also has a significant impact on the outcomes that can be achieved. Our reports do not yet capture the full range of intended product outcomes, nor the variety of different ways of implementing our products. What we do know is that the more we can engage with our customers about best practices that can support the integration of learning technologies into their teaching, the more likely they will be to achieve their desired outcomes.

We have commissioned PricewaterhouseCoopers LLP ('PwC') to audit the efficacy statements set out in our Research Reports. This is to demonstrate that the statements accurately reflect the research that has been carried out. PwC's audit report can be found at the end of this document.

The journey ahead

Delivering on our reporting commitment has never been our ultimate goal; what matters most to us is helping more learners, learn more. Our aspiration is to explore what works, for whom, and why; and to encourage discussion about questions such as: What outcomes matter most to students? What should teaching and learning look like? What evidence should we apply to its design? And how should we evaluate impact?

We are excited to continue partnering with educators and others in the field in order to better understand how interactions between educators, students and learning technology can enhance outcomes. We have also been energized to see others in the education sector begin to focus on efficacy and research — though we recognize that their application in education is still nascent. In order to accelerate the emergence of its full potential we are already developing new ways of partnering with educators, researchers and institutions so we can advance this work together. In doing so, we will continue to advocate for the need to apply rigorous evidence to improve the outcomes of teaching and learning, while also seeking to ensure that evidence captures customers' experiences and is relevant and useful to educators in their practice.

Special thanks

We want to thank all the educators, students, research institutions and organizations we have collaborated with to date. We are spurred on by the growing number of opportunities for us to learn from others in the sector who are beginning to tackle the same challenges. If you are interested in partnering with us on future efficacy research, have feedback or suggestions for how we can improve, or want to discuss your approach to using or researching our products, we would love to hear from you at efficacy@pearson.com. If we, as a sector, tackle this together, we will help more learners learn more.

Kate Edwards
Senior Vice President,
Efficacy and Research, Pearson
April 3 2018

Findings in brief

Pearson sought to explore whether the use of Mastering Chemistry, an online tutorial system designed to help students with chemistry concepts, problem-solving skills and quantitative reasoning, is related to students' course scores and exam scores.

This Research Report presents findings from two research studies: one correlational study conducted at a highly selective, four-year research university for students enrolled in a general chemistry course; and one quasi-experimental study conducted at Ohio State University, a primarily residential, land-grant public university known for academic research in science, for students enrolled in General Chemistry I and II. Our aim in using mainly correlational study designs was to seek out possible relationships between the use of Mastering Chemistry and students' course and exam scores to identify areas of focus for potential future research using more rigorous causal study designs.

The findings appear alongside details of the research studies, including descriptions of the samples studied, methods of analysis, results, limitations and generalizability, and notes on possible future research.

The report also summarizes the context surrounding the findings, including the research that informed the design and development of the product, the history of the product in the market, how educators use the product, and its intended outcomes.

The findings are inseparable from their surrounding context and the design of the study that produced them. To learn more about these elements, follow the links to our Technical Reports in the **Research studies** section.

In the context of the study conducted at the highly selective research university, Pearson found that, after controlling for selected student characteristics:

— In Fall 2016, making 20 additional problem attempts was associated with a 1 percentage-point increase in final exam scores.
— In Fall 2016, making 30 additional problem attempts was associated with a 1 percentage-point increase in total course scores.
— In Winter 2017, making 24 additional problem attempts was associated with a 1 percentage-point increase in final exam scores.
— In Winter 2017, making 30 additional problem attempts was associated with a 1 percentage-point increase in total course scores.

In the context of the study conducted at Ohio State University, Pearson found that, after controlling for selected student characteristics:

— In Fall 2016, use of Mastering Chemistry was associated with higher course performance than was use of Sapling in terms of final exam scores (7% increase in percentile rank for an average student in the Sapling group), course grades (5% increase in the percentile rank for an average student in the Sapling group), and binary grades (pass/fail) (2% increase in the percentile rank for an average student in the Sapling group).
— In Spring 2017, use of Mastering Chemistry was associated with higher course performance than was use of Sapling in terms of course grade (20% increase in the percentile rank for an average student in the Sapling group) and binary grades (17% increase in the percentile rank for an average student in the Sapling group).
— In Fall 2016 and Spring 2017, when controlling for student prior achievement and demographic characteristics, the number of problems attempted was significantly and positively related to final exam scores, course grades, and binary grades (pass/fail).

The complete statements, including a number of descriptive statements about the efficacy of Mastering Chemistry, are set out in the boxes titled "Efficacy statements" on pages 14 and 19. These statements have been subject to assurance by PwC, whose report can be found at the end of this Research Report.

Product design and development

Product overview

Mastering Chemistry is an online tutorial system designed to help students achieve mastery of chemistry concepts, problem-solving skills and quantitative reasoning. It is a further development of Cybertutor, an early tutorial system for chemistry instruction (Morote, Kokorowski, & Pritchard, 2002). Tutorials feature hints and targeted wrong-answer feedback that emulate a human tutor and help students with tough concepts in order to achieve proficiency quickly. Mastering Chemistry is designed to accompany a number of textbooks written in the chemistry discipline.

Mastering Chemistry is also designed to enhance and improve the following outcomes:

— Student engagement and learning experiences
— Problem solving skills that can be applied to everyday applications and later courses
— Student achievement — e.g., in homework assignments and end of course examination results

The full list of the outcomes this product is intended to support, accompanied by a brief description, can be found in the appendix of this report.

Foundational research underpinning the design

Mastering Chemistry is an online tutorial system designed to support students as they learn chemistry concepts and skills. These kinds of systems serve a number of the same functions that human tutors perform, including presenting problems, providing guidance (e.g., hints), evaluating students' responses, providing detailed feedback, and choosing content appropriate for a student's current level of understanding. Research has demonstrated the efficacy of a number of tutorial systems, suggesting that well-designed systems can be as effective as human tutors (VanLehn, 2011).

Furthermore, chemistry education research has highlighted the importance of high quality, self-directed exercises — like those that Mastering Chemistry provides — in promoting achievement outcomes, such as higher final course grades (Cuadros, Yaron, & Leinhardt, 2007).

The design of Mastering Chemistry incorporates numerous principles from learning science, with the goal of helping all students achieve mastery of core chemistry knowledge and skills. What follows is a summary of some specific learning science research that underpins the design of Mastering Chemistry.

Adaptivity

Adaptive learning tools can be defined as "technology-based artifacts that interact with students and vary presentation based upon that interaction" (Murray & Perez, 2015). Research has identified two categories of adaptivity in learning technologies (VanLehn, 2006). Mastering Chemistry uses elements of both kinds of adaptivity to deliver a personalized learning experience for each student.

One type relates to adaptive responses to student inputs, such as immediate feedback that is specific to the student's attempt. When students make an error on tutorial problems in Mastering Chemistry, they often receive immediate wrong-answer specific feedback to address that particular error (see **Feedback** below).

The other type of adaptivity relates to modifying a learning sequence based on the student's current proficiency. One way in which this can be done is by estimating mastery based on student performance, and ensuring that students receive enough practice to achieve fluency with the content. This "Knowledge Tracing" has been used to great effect in educational research (e.g., Corbett & Anderson, 1995).

Adaptive Follow-Up assignments offer Mastering Chemistry users additional graded practice in areas in which they are still struggling. These homework assignments are dynamically created by Mastering Chemistry, based on the student's performance on an assignment.

Dynamic Study Modules also give students further opportunities to practice topics they are struggling with. In the modules, students answer questions and indicate their level of confidence in their responses. By answering one question correctly and confidently, students can demonstrate mastery of topics they already understand, and where they are incorrect or uncertain, they receive extra practice and targeted narrative. This feature enables continuous assessment of performance and activity, then uses data and analytics to provide personalized content in real-time to reinforce concepts that target each student's particular strengths and weaknesses.

All the adaptive Mastering Chemistry features described above aim to enhance achievement.

Active, constructive, and interactive learning

Mastering Chemistry problems and associated features embody what are known as *active*, *constructive*, and *interactive* approaches to learning (Chi, 2009). Each of these approaches has been shown to be more effective for learning than passive approaches, in which learners' sole activity is the intake of information (e.g., listening to a lecture).

Active learning is characterized by doing something during learning, and it ranges widely — from taking notes during a lecture, to searching a textbook for information, or answering questions that test memory of facts.

Constructive learning refers to activities in which a student produces a novel idea or other output that goes beyond previously encountered information: for example, the solution to a new problem.

Interactive learning involves a back-and-forth interaction between the student and another individual, such as a human or digital tutor.

Research demonstrates that, on average, each of these approaches to learning is more effective than passive approaches, with efficacy increasing as learning activities progress from active to constructive to interactive forms (Chi, 2009).

Mastering Chemistry generally supports learners to go beyond passive activities, with many problems supporting active, constructive, and interactive learning.

Active, constructive, and interactive activities can be integrated into the classroom through use of Learning Catalytics. This classroom engagement tool uses the devices students already bring to class — smartphones, tablets, or laptops — to pose questions and engage them in a variety of tasks. Instructors receive real-time analytics that they can use to generate discussion and to assess students' performance in real-time.

One way Mastering Chemistry encourages constructive learning is with simulations. Simulations require students to apply their learning by critically evaluating information, deciding on next steps to take, and solving novel problems. This feature aims to develop critical reasoning and problem solving skills.

Many Mastering Chemistry items are accompanied by optional hints that students can access for additional help. These hints are intended to help students successfully complete an item when they might not be able to otherwise. Declarative hints provide advice on how to approach the problem, guiding students to the final answer, and Socratic hints break a problem down into smaller sub-problems. This interactive feature aims to enhance achievement by helping students successfully complete items that they might struggle with otherwise.

The hints, feedback, Dynamic Study Modules, and Adaptive Follow-Up Assignments all provide opportunities for a more interactive learning experience.

Testing effect

Being tested on information improves learning and memory more than simply re-studying that same information. This *testing effect* is a well-established psychological phenomenon, having been demonstrated in a large number of laboratory and classroom settings (Roediger & Karpicke, 2006). Testing is believed to support learning by requiring retrieval of information from memory, thereby strengthening the ability to recall that information again later.

When using Mastering Chemistry, students engage in retrieval practice whenever they recall information in order to answer questions in homework, Adaptive Follow-Up Assignments, or Dynamic Study Modules. Research suggests that retrieval practice contributes both to long-term retention and to learning in a way that can flexibly transfer to help solve new problems (Carpenter, 2012; Roediger & Butler, 2011).

It is worth noting that research on the testing effect has found that it is not only successful retrieval of correct information that helps learning. Even if a student does not get the problem correct on the first try, when a student is given feedback, testing is still found to be more beneficial than passive studying (Roediger & Butler, 2011). In addition, most courses using Mastering Chemistry allow students to make multiple attempts; there is a benefit for memory when successfully retrieving correct information on a re-attempt of a question, particularly if that retrieval is strenuous (Pyc & Rawson, 2009).

Scaffolding

Research has found that novices learn and process information in fundamentally different ways to those with more background knowledge (Chi, Feltovich, & Glaser, 1981). Specifically, novices lack a body of relevant knowledge and strategies to draw upon to help them solve new problems or learn new information. As such, it is critically important to provide novice learners with "scaffolds", or supports, to help them achieve learning outcomes that might otherwise be out of reach.

Scaffolding can support learning by helping students structure complex tasks and by highlighting aspects of problems that require special attention (Reiser, 2004). And scaffolding in technology-enhanced learning environments has shown particular promise in supporting novice learning (Sharma & Hannafin, 2007).

Mastering Chemistry provides scaffolds alongside assessment items. In many items, struggling students can access optional hints, similar to what they might receive from an instructor. These hints are a form of scaffolding in which students are provided with support that allows them to achieve tasks that they might otherwise struggle with or fail to achieve. Mastering Chemistry hints do this by breaking down problems into smaller steps and by helping students recognize specific concepts or issues they must consider to solve the problem. This approach is aligned to research showing that studying step-by-step examples of expert problem-solving helps develop problem-solving skills (Atkinson, Derry, Renkl, & Wortham, 2000).

Feedback

Learning is enhanced when students are provided with regular feedback on their performance. Research on computer-based feedback systems has shown that feedback that explains or otherwise elaborates on the correctness of a response is more effective than feedback that only indicates whether the response was right or wrong (Van der Kleij, Feskens, & Egge, 2015).

Research on feedback timing (i.e., immediate vs. delayed) has produced a wide range of results, but findings generally indicate that immediate feedback is appropriate when students are learning new, difficult tasks (Shute, 2008).

Mastering Chemistry provides students with immediate feedback on problems they attempt. Feedback always indicates whether the student's response was correct, and for many problems the feedback also explains why an answer is correct (in the event of a correct response) or addresses a specific mistake or misunderstanding (in the event of an incorrect response).

History and reach of Mastering Chemistry

The Mastering product line, of which Mastering Chemistry is a part, launched more than 15 years ago. In that time the various products under the Mastering umbrella have been used by more than 20 million students.

First launched in 2004, Mastering Chemistry has been used by over 4 million students in general chemistry courses. Earlier versions under the names of CyberTutor and MasteringChemistry (no space) have evolved into the current product.

Mastering Chemistry is currently used by 600,000 students per year at the higher education level.
The platform is used in the United States, Canada, United Kingdom, parts of Europe and South America.

Intended product implementation

Overview of intended product implementation

We aim to keep Mastering Chemistry flexible enough to allow our customers to make choices about how best to implement it to address their needs, and to allow them to tweak their practice over time to improve the experience and outcomes.

Customers have told us that they have seen a greater impact when Mastering Chemistry is:

— Required
— Assigned for at least 10% credit
— Assigned with due dates to help keep students on schedule
— Used as a formative assessment tool to prepare learners for summative assessments (this includes fading away supports such as learning aids over time so that learners are better prepared for assessments that don't use them)

Mastering Chemistry provides a range of tools and content that can be used to gauge students' understanding of the material in pre- and post-class activities. In addition, Mastering Chemistry provides tools and activities for in-class work.

Product research

The purpose of the research done to date was to explore the relationship between Mastering Chemistry usage and students' access and experience, standard of achievement and/or level of competence. Given the alignment of Mastering Chemistry with the learning science principles discussed in the **Product design and development** section above, we hypothesize that usage of Mastering Chemistry will have a positive relationship with learner outcomes, particularly in terms of problem solving skills, and achievement (see Appendix for the full list of intended outcomes).

Specifically, the activities in Mastering Chemistry and the testing effects those activities support, combined with the benefits of scaffolding and elaborated feedback, are designed to enhance student learning. As a result, we should observe a correlation between student usage of Mastering Chemistry and exam and course grades. Additionally, to the degree that Mastering Chemistry is effective for learning, students who use Mastering Chemistry may tend to earn higher exam and course grades than students who have not used it, after controlling for several variables associated with student achievement.

For this first phase of our efficacy journey, we mainly focused on exploring correlational rather than causal relationships between our products and learner outcomes. Demonstrating causation is complex and requires significant investment; our correlational studies identify relationships that may be worth investigating further with causal study designs in future research.

Existing research

In 2018 Pearson researchers completed a systematic search and review of research articles published since 2012 that assessed the impact of Mastering Chemistry on learner outcomes. Our criteria for the review and inclusion of existing published research on our products were designed based on US Department for Education What Works Clearinghouse guidance. Based on these guidelines, in order for research to be included in this Efficacy Report on Mastering Chemistry it needed to meet a number of criteria, including that the study was published in the past five years, examined at least one intended learner outcome category, and reported results in enough detail that the research could be properly evaluated. For more information on this see the Pearson Efficacy Reporting Framework dated April 3 2018.

In our initial screening, we discovered 110 studies. After an initial review we found that four contained information relevant to Mastering Chemistry. Following an in-depth review, we discovered that no existing published studies met the necessary criteria to be included in this Efficacy Report. For the initial screening list and a list of the subset of studies that contained information relevant to Mastering Chemistry but did not meet our criteria to be included here see the Pearson Efficacy Reporting Framework dated April 3 2018.

Research studies

There are two new studies, conducted by SRI International, that form the basis of the Efficacy Report for Mastering Chemistry. The research questions and findings for each study are set out in detail below, including the efficacy statements generated by those studies.

Study 1

Study citation	Study of Mastering Chemistry at selective research university — SRI International — March 2018
Research study contributors	**SRI International** Rebecca Griffiths Jared Boyce Shuai Wang Tallie Wetzel
Research questions	1. To what extent were students satisfied with their experience using the product? 2. What are the relationships among incoming student proficiency, product use variables (e.g., frequency, units completed, features used), and student outcomes? For the complete list of questions addressed in this research study, including those without related efficacy statements, see the Technical Report.
Related intended outcomes category	— Access and experience — Standard of achievement or level of competence
Study design	Relational (correlational, not predictive) This study examined the association between the use of Mastering Chemistry and students' achievement on their course exams in General Chemistry in the Fall 2016 and Winter 2017 semesters. The textbook used in the course was *Chemistry: A Molecular Approach* by Nivaldo J. Tro.
Metrics studied	— Number of unique problems attempted — Final exam scores — Course grades — Student self-report survey data
Description of sample	This study is limited to participants at one institution: a highly selective research university. The institution asked to remain anonymous in our efficacy reporting. The study sample were students enrolled in the Fall 2016 and Winter 2017 semesters in General Chemistry 31A and B. The vast majority of students in the sample were enrolled full-time. Most had not yet declared a major. The approximate ratio of female to male students was 2:1. Most students in the sample spoke English as their primary language and most had a parent who attended college. The high standard of academic achievement at this highly selective university posed an interesting challenge, wherein the students would be using Mastering Chemistry to advance, rather than remediate, their knowledge. General Chemistry at the university was taught in lecture sections of approximately 180–200 students by two instructors. The instructors taught using a mixture of lectures and scaffolded problem-solving. Mastering Chemistry was used outside class time for homework, practice, and to introduce new concepts, as part of a "flipped" instructional model. Students were given multiple assignments per week and expected to come to lectures prepared to do problem solving.

Sample size	For the Fall semester 2016, course outcomes data was available for 442 students and Mastering Chemistry usage data was available for 456 students. In the same semester, 413 students responded to an end-of-semester survey. For the Winter semester 2017, course outcomes data was available for 396 students and Mastering Chemistry usage data was available for 405 students. After merging the survey, course outcomes, and usage datasets — dropping any results that could not be linked through all three datasets — the final analytical samples consist of 390 students for the Fall semester 2016, and 345 students for the Winter semester 2017.
Analysis	Data from surveys and site visits was 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 product. 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. Linear regression models (hierarchical regression models when appropriate) were used to examine the relationship between the level of student use of Mastering Chemistry and achievement outcomes, controlling for students' baseline characteristics. The indicator of use examined was the number of unique problems attempted.
Results	In the Fall 2016 end-of-semester survey, students rated Wrong Answer Feedback as by far the most frequently used feature. 87% of respondents said that they "often" or "sometimes" used this feature. 87% of students also said they found this feature "very" or "somewhat" helpful. The second most frequently used feature was Videos (78%). 70% of students reported that Mastering Chemistry helped them come to class better prepared. 52% of students reported that they had access to a greater variety of learning materials. 58% of students reported that Mastering Chemistry helped them prepare for tests/quizzes. A lower percentage of students reported that Mastering Chemistry enabled them to receive more personalized feedback (29%). There were also fewer students who reported that Mastering Chemistry increased their enjoyment of the course (26%). More than 80% of students reported 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", with 59% saying it was not easy. When controlling for self-reported 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. There were no significant differences in the relationship between usage and outcomes for different types of students.

Efficacy statements

In the context of this study, conducted at a highly selective research university for students enrolled in the Fall 2016 and Winter 2017 semesters, Pearson is able to make the following relational (correlational, not predictive) statements about the efficacy of Mastering Chemistry:

— In Fall 2016, making 20 additional problem attempts was associated with a 1 percentage-point increase in final exam scores.
— In Fall 2016, making 30 additional problem attempts was associated with a 1 percentage-point increase in total course scores.
— In Winter 2017, making 24 additional problem attempts was associated with a 1 percentage-point increase in final exam scores.
— In Winter 2017, making 30 additional problem attempts was associated with a 1 percentage-point increase in total course scores.

Note that we have multiplied the regression coefficients obtained from the linear regression models in order to express all the above relational (correlational, not predictive) statements in terms of 1 percentage-point increases. We have done this for ease of interpretation and effective communication with a broad audience.

It should also be noted that all these statements reflect a relationship between Mastering Chemistry and performance above and beyond students' self-reported prior achievement. Therefore, it is not simply the case that high-achieving students tend to perform well on multiple aspects of the course. The relationships expressed above were calculated across all students in the sample and capture the contribution of Mastering Chemistry to course performance once self-reported prior achievement has already been accounted for.

In the same context, Pearson is able to make the following descriptive statements about the efficacy of Mastering Chemistry.
Out of 413 students who responded to the survey:

— At least 80% of students reported that it was easy to login to Mastering Chemistry, find out how much work they had finished, and/or get their account set up.
— 89.8% of students reported it was easy to find their grade on a homework assignment.
— 47.5% of students reported that it was easy to find the relevant information in the textbook.
— 39.0% of students reported that it was easy to get help when they don't understand something.
— 52.3% of students reported it was “mostly” or “very” true that they had access to a greater variety of learning materials when using Mastering Chemistry.
— 48.9% of students indicated it was "mostly" or "very" true that they had access to a greater variety of learning materials when using Mastering Chemistry.
— 70.2% of students said it is "mostly" or "very" true that they were better prepared for class when using Mastering Chemistry.
— 57.6% of students say it is “mostly” or “very” true that Mastering Chemistry helped them prepare for tests and quizzes.
— 50.4% of students reported it is “mostly” or “very” true that Mastering Chemistry helped increase their confidence in their ability to learn new things on their own.
— 34.4% of students indicated that it is “mostly” or “very” true that when using Mastering Chemistry, they were able to use different approaches to help them learn.
— 49.9% of students reported it was “mostly” or “very” true that Mastering Chemistry helped them learn new problem solving skills.

Limitations and generalizability	*No control or comparison group:* The study did not make use of a comparison group of students who did not use Mastering Chemistry. Without this, we are unable to estimate the impact of Mastering Chemistry use versus non-Mastering Chemistry use on student outcomes. *Reliability of self-reported data:* We relied on self-reported student background data, including prior achievement. 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. *The generalizability of the study:* The study made use of data at only one school for a specific chemistry course. Replication of findings at other schools with a different type of setting would be needed to be able to generalize about the findings.
Future research	Future studies could explore whether these findings can be replicated at other schools so we can understand more about what works, when, where, how, for whom and why. Future studies could also make use of more rigorous research designs. For example, an experimental or quasi-experimental research design could assess whether use of Mastering Chemistry leads to higher exam scores — that is, whether the relationship we observed was causal in nature.

Read about this research in more detail in our Technical Report

Study 2

Study citation	Quasi-experimental study of Mastering Chemistry Ohio State University — SRI International — March 2018
Research study contributors	**SRI International** Rebecca Griffiths Jared Boyce Shuai Wang Tallie Wetzel
Research questions	1. To what extent were instructors and students satisfied with their experience using the product and with the training and support provided? 2. Have students who used Mastering Chemistry achieved better completion and progression outcomes than have similar students who did not use the product? 3. What are the relationships among incoming student proficiency, product use variables (e.g., frequency, units completed, features used), and student outcomes? For the complete list of questions addressed in this research study, including those without related efficacy statements, see the Technical Report.
Related intended outcomes category	— Access and experience — Standard of achievement or level of competence
Study design	Quasi-experimental — but due to educator confounders, only relational (correlational, not predictive) claims were made. This study examined the association between the use of Mastering Chemistry and students' achievements on their course exams in General Chemistry in the Fall 2016 and Spring 2017 semesters, compared to the use of a competitor product. That is, students enrolled in the General Chemistry course used either Mastering Chemistry or a competitor product for assignments. Students in the two groups demonstrated baseline equivalence in terms of prior achievement, age, and gender. Thus, no statistical matching on the students was used, although all three variables were included as covariates in the analysis. The textbook used in the Mastering Chemistry classes was reported to be Chemistry: *The Central Science* by Brown, Lemay, Bursten, Murphy, Woodward, and Stoltzfus (13th edition).
Metrics studied	— Final exam scores — Total course grades — Binary outcome (pass/fail) — Student self-report survey data
Description of sample	This study is limited to participants at one institution: Ohio State University (OSU). Located in Columbus, Ohio, this primarily residential, land-grant public university is the third largest university campus in the US. Ohio State University is known for academic research in science as well as educational research throughout its physical science departments. The study sample included students enrolled in the Fall 2016 and Spring 2017 semesters in General Chemistry I and II (Chem 1210 and Chem 1220). The majority of students in the sample were enrolled full-time and most had declared a major. The approximate ratio of female to male students was 3:2. Most students in the sample spoke English as their primary language and most had a parent who attended college. Mastering Chemistry was primarily used to assign, support and grade homework. Mastering Chemistry was also used to encourage students to come to class better prepared and, in one case, to "flip" the classroom: using interactive features during class time.

Sample size

For the Fall semester 2016, course outcomes data was available for 2,696 students: 1,063 using Mastering Chemistry and 1,633 using Sapling, a Macmillan Education product. In the same semester, 1,878 students (808 using Mastering Chemistry, 1,069 using Sapling) responded to an end-of-semester survey.

For the Spring semester 2017, course outcomes data was available for 2,004 students: 1,326 using Mastering Chemistry and 678 using Sapling.

After merging the survey and course outcomes datasets, and dropping any students missing data that was important for the analysis, the final analytic samples for the comparative impact analysis (Mastering Chemistry users vs. Sapling users) consisted of 1,700 students (742 using Mastering Chemistry, 958 using Sapling) for the Fall semester 2016, and 1,137 students (782 using Mastering Chemistry, 355 using Sapling) for the Spring semester 2017.

The final analytic samples for the analysis examining the relationship between Mastering Chemistry and course performance consisted of 623 students for the Fall semester 2016, and 774 students for the Spring semester 2017.

Analysis

For the comparative impact analysis between Mastering Chemistry users and Sapling users, linear regression models and, when warranted, hierarchical regression models (i.e., students clustered within sections) were used to estimate the impact of using Mastering Chemistry on student outcomes in terms of achievement and completion.

Because the researchers did not randomly assign students to conditions (Mastering Chemistry vs. Sapling), the baseline composition of students in courses using Mastering Chemistry was compared to that of students in courses that did not, to rule out selection bias. To establish the degree of baseline equivalence, researchers compared the composition of the two groups on a set of baseline covariates, including gender, age, and baseline measures of academic preparation (e.g., SAT or ACT score). Relying on What Works Clearinghouse standards, the researchers considered groups within 0.25 standard deviations in age, gender, and academic preparation to be acceptably equivalent.

None of the prior achievement or student background characteristics differed substantially between the Mastering Chemistry students and the Sapling students for the Fall 2016 or Spring 2017 sample. The effect sizes (i.e., standardized differences) between the two groups were all less than 0.2, which is within the What Works Clearinghouse standards. However, because the number of instructors was too small to be included in the statistical model, any differences between Mastering Chemistry instructors and Sapling instructors could not be addressed in the analyses. Thus, we were only able to make correlational statements on the findings, instead of causal statements.

In addition to the comparative impact analysis with the Sapling group, the researchers also examined the relationship between Mastering Chemistry usage and achievement outcomes for the Mastering Chemistry group. For these analyses, the researchers used linear regression models (and hierarchical regression models when appropriate) to examine the relationship between the level of students' use of Mastering Chemistry and their achievement outcomes, controlling for students' baseline characteristics.

In these analyses, Mastering Chemistry usage was defined by the number of unique problems attempted. The achievement outcomes examined were final exam scores, course grades, and binary grades (i.e., passing the course).

Data from surveys and site visits was 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 product. 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.

Results

In the Fall semester 2016, for three of the outcome measures examined (final exam scores, course grades, and binary grades) usage of Mastering Chemistry was significantly associated with better outcomes than was usage of Sapling, when controlling for student prior achievement, age, and gender, as well as accounting for the section-level effects. However, instructor confounders were not addressed in the analyses, limiting us to correlational conclusions.

In the Spring semester 2017, for two of the four outcome measures examined (course grades and binary grades), usage of Mastering Chemistry was significantly associated with better outcomes on the two measures than was usage of Sapling, when controlling for the same factors but not teacher confounders.

When examining the relationship between Mastering Chemistry usage and achievement for the Mastering Chemistry group, there was a significant association between Mastering Chemistry use and student chemistry performance. In particular, controlling for student prior achievement and demographic characteristics, the number of problems attempted was positively and significantly related to final scores, total scores and binary grades in both the Fall 2016 and Spring 2017 semesters.

In the Fall 2016 end-of-semester survey, students using Mastering Chemistry rated Wrong Answer Feedback as by far the most frequently used feature, followed by Hints and Videos. 89% of respondents said they “often” or “sometimes” used Wrong Answer Feedback. Hints followed, with 76% of students reporting use of this feature, followed by Videos and Learning Catalytics. Dynamic Study Modules ranked lowest, with only 46% of students reporting they used this feature “often” or “sometimes”.

More than 90% of students reported that logging in, finding out how much work they had finished, getting their account set up, and/or finding their grades on a homework assignment were easy Mastering Chemistry functions to use. The function with the lowest percentage of students who reported ease of use was “finding the relevant information in the digital textbook”, though a majority of students still reported that this was easy to do (62%).

76% of students indicated it was "mostly true" or "very true" that Mastering Chemistry helps them come to class better prepared. 69% indicated it was "mostly true" or "very true" that they had access to a greater variety of learning materials. 73% indicated it was "mostly true" or "very true" that Mastering Chemistry helped them prepare for tests/quizzes.

A lower percentage of students indicated it was "mostly true" or "very true" that Mastering Chemistry enabled them to receive more personalized feedback (46%). There were also fewer students who indicated it was "mostly true" or "very true" that using Mastering Chemistry increased their enjoyment of the course (44%).

Efficacy statements

In the context of this study, conducted at Ohio State University for students enrolled in General Chemistry I and II, Pearsonis able to make the following comparative statements about the efficacy of Mastering Chemistry:

— In Fall 2016, use of Mastering Chemistry was associated with higher course performance than was use of Sapling in terms of final exam scores (7% increase in percentile rank for an average student in the Sapling group), course grades (5% increase in the percentile rank for an average student in the Sapling group), and binary grades (pass/fail) (2% increase in the percentile rank for an average student in the Sapling group).

— In Spring 2017, use of Mastering Chemistry was associated with higher course performance than was use of Sapling in terms of course grade (20% increase in the percentile rank for an average student in the Sapling group) and binary grades (17% increase in the percentile rank for an average student in the Sapling group).

In the same context, Pearson is able to make the following relational (correlational, not predictive) statement about the efficacy of Mastering Chemistry:

— In Fall 2016 and Spring 2017, when controlling for student prior achievement and demographic characteristics, the number of problems attempted was significantly and positively related to final exam scores, course grades, and binary grades (pass/fail).

It should be noted that these statements reflect a relationship between Mastering Chemistry and performance above and beyond students' prior achievement. Therefore, it is not simply the case that high-achieving students tend to perform well on multiple aspects of the course. The relationships expressed above were calculated across all students in the sample and capture the contribution of Mastering Chemistry to course performance once prior achievement has already been accounted for.

In the same context, Pearson is able to make the following descriptive statements about the efficacy of Mastering Chemistry.

Out of 808 students who responded to the survey:

— At least 90% of students reported that it was easy to login to Mastering Chemistry, find out how much work they had finished, get their account set up, and/or find their grade on a homework assignment.

— 65% of students reported that it was easy to get help when they didn't understand something in Mastering Chemistry and 62% reported it was easy to find the relevant information in the textbook.

— 75.9% of students said it is "mostly" or "very" true that they were better prepared for class when using Mastering Chemistry.

— 68.5% of students reported it was "mostly" or "very" true that they had access to a greater variety of learning materials when using Mastering Chemistry.

— 73.2% of students reported it is "mostly" or "very" true that Mastering Chemistry helped them prepare for tests and quizzes.

— 67.8% of students indicated it was "mostly" or "very" true that they were more engaged in the learning experience when using Mastering Chemistry.

— 61.8% of students reported it is "mostly" or "very" true that Mastering Chemistry helped increase their confidence in their ability to learn new things on their own.

— 56.9% of students indicated that it is "mostly" or "very" true that when using Mastering Chemistry, they were able to use different approaches to help them learn.

— 58.8% of students reported it was "mostly" or "very" true that Mastering Chemistry helped them learn new problem solving skills.

Limitations and generalizability	*Results are correlational and not causal:* The study design does not allow us to determine whether using Mastering Chemistry would actually lead students to improve their course performance. The researchers were not able to rule out the influence of all the confounding factors in student achievement. For example, instructors in the treatment condition had more experience using Mastering Chemistry than the Sapling instructors in the comparison condition had using Sapling; so instructors' degree of experience in using the respective products may explain at least a portion of the difference in course achievement outcomes. *Missing data:* Due to issues with the administration of the student post-survey, there was a substantial amount of missing data, arising first from low survey response rates (only around 66% of students who had responded to the pre-survey responded to the post-survey) and second with problems matching individual student IDs across discrete data sources. *Product implementation:* Little is known about how Sapling was implemented. Thus, differences in student performance could be related to differences in the ways the two products were implemented. In addition, during the Fall semester 2016, Mastering Chemistry instructors had more experience using the product than instructors in the comparison condition had using Sapling. However, both products were used primarily as a homework tool, both contributed similar amounts to students' grades in the course, and in the instructor survey, Sapling instructors all reported feeling very prepared to use the product and having between one and four years of experience using the product. *The generalizability of the study:* The study made use of data at only one school for a specific chemistry course. Replication of findings at other schools with a different type of setting would be needed to be able to generalize the findings.
Future research	Future research could also explore whether these findings can be replicated at other schools so we can understand more about what works, when, where, how, for whom and why. Future studies could make use of more rigorous research designs. For example, an experimental research design could assess whether use of Mastering Chemistry leads to higher exam scores — that is, whether the relationship we observed is causal in nature. Where random assignment to the treatment condition is not possible, having a larger sample of instructors would permit statistical control of teacher-level factors, which would also strengthen efficacy statements.

Read about this research in more detail in our Technical Report

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Appendix 1: full list of intended outcomes

Outcomes related to learner access and experience

Intended outcome 1

Learners can access digital learning materials from personal computer, tablet or smart phone anytime.

Mastering Chemistry is designed to be accessible at any time via phones and tablets, as a means of increasing engagement in the classroom and beyond.

Intended outcome 2

Learners can successfully use Mastering Chemistry without or with little technical support.

Mastering Chemistry is designed to be accessible at any time via phones and tablets, as a means of increasing engagement in the classroom and beyond.

Intended outcome 3

Learners can access the learning content/subject matter.

Mastering Chemistry functions with standard operating systems and hardware, so that students are able to access from their home or lab computer successfully.

Intended outcome 4

Learners are engaged and have a positive learning experience.

Mastering Chemistry has a number of features designed to fully engage learners, from interactive pre-lecture videos that provide an introduction on key topics, to embedded assessment to help students prepare before a lecture. An additional key feature is a classroom engagement tool, *Learning Catalytics,* which augments lectures by providing guiding questions for in-class discussion that encourage student participation and foster a positive learning experience.

Outcomes related to timeliness of completion

Intended outcome 5

Learners complete the course first time.

Mastering Chemistry is designed to provide guidance and support that helps students master content and gain the skills necessary to pass the course first time.

Intended outcome 6

Learners attend class.

All of the resources in Mastering Chemistry are intended to support student learning, giving students the confidence to attend class and get the most out of their study.

Intended outcome 7

Learners complete assignments on time.

Mastering Chemistry learners benefit from self-paced tutorials featuring specific, wrong-answer feedback and hints that emulate a human tutor with the aim of making them more likely to complete activities and, ultimately, the course on time.

Outcomes related to standard of achievement or level of competence

Intended outcome 8

Learners pass the chemistry course first time taking the course.

Mastering Chemistry is designed to provide guidance and support that helps students master content and gain the skills necessary to pass the course first time.

Intended outcome 9

Learners pass assignments in Mastering Chemistry.

The instructional content, practice materials, and assessments in Mastering Chemistry cover all of the objectives for students to pass assignments.

Intended outcome 10

Learners pass the external exam.

Students using Mastering Chemistry can practice problems that follow the same problem-solving process outlined in their textbooks. Learners will not only gain an understanding of key concepts, but an understanding of the skills required to pass the external exam.

Intended outcome 11

Learners gain critical reasoning and problem solving skills that can be applied to everyday applications and later courses.

Mastering Chemistry helps students to have a full understanding of critical reasoning and problem solving skills, which they can apply to everyday applications and future courses.

Outcomes related to learner progress

Intended outcome 12

Learners progress to MCAT.

Mastering Chemistry is intended to instill an understanding of core scientific principles that give students the confidence to consider a career in a related field, such as medicine, and progress to taking The Medical College Admission Test (MCAT).

Intended outcome 13

Learners progress/choose next level chemistry courses.

Students are taught skills in the context of scientific principles that relate to more advanced courses. Knowledge gained from Mastering Chemistry should encourage students to progress to the next course.

Intended outcome 14

Learners demonstrate increased performance in courses after general chemistry.

In addition to completing the chemistry course, Mastering Chemistry aims to help students show success in subsequent courses.

Independent limited assurance report to the directors of Pearson plc

The directors of Pearson plc ("Pearson") engaged us to provide limited assurance over the efficacy statements clearly identified by the box titled 'Efficacy statements', including reference to the study design type, in the Pearson Mastering Chemistry Efficacy Research Report dated April 3 2018 ("Research Report").

Our conclusion

Based on the procedures we have performed and the evidence we have obtained, nothing has come to our attention that causes us to believe that the efficacy statements set out in the Pearson Mastering Chemistry Research Report have not been prepared and reported, in all material respects, in accordance with the Pearson Efficacy Reporting Framework dated April 3 2018.

This conclusion is to be read in the context of what we say in the remainder of our report.

Efficacy statements

The scope of our work was limited to assurance over the efficacy statements clearly identified by the box titled 'Efficacy statements', including reference to the study design type, in the Mastering Chemistry Research Report. Our assurance does not extend to other information presented in the Research Report.

Professional standards applied and level of assurance

We performed a limited assurance engagement in accordance with International Standard on Assurance Engagements 3000 (Revised) *Assurance Engagements other than Audits and Reviews of Historical Financial Information*, issued by the International Auditing and Assurance Standards board. A limited assurance engagement is substantially less in scope than a reasonable assurance engagement in relation to both the risk assessment procedures, including an understanding of internal controls, and the procedures performed in response to the assessed risks.

Our independence and quality control

We applied the Institute of Chartered Accountants in England and Wales (ICAEW) Code of Ethics, which includes independence and other requirements founded on fundamental principles of integrity, objectivity, professional competence and due care, confidentiality and professional behaviour.

We apply International Standard on Quality Control (UK) 1 and accordingly maintain a comprehensive system of quality control including documented policies and procedures regarding compliance with ethical requirements, professional standards and applicable legal and regulatory requirements.

Our work was carried out by an independent and multi-disciplinary team including educators, statisticians, and experts in reporting and assurance.

Reporting and measurement methodologies

The efficacy statements need to be read and understood together with the Pearson Efficacy Reporting Framework dated April 3 2018 (the "Framework"), available on Pearson's website[i] at https://www.pearson.com/efficacy-reporting-framework. The absence of a fully comprehensive set of generally accepted rules for identifying learner outcomes and defining, assessing and reporting the efficacy of educational products allows for different, but acceptable, ways of measuring product efficacy and reporting findings as efficacy statements. This could affect comparability between Pearson's efficacy reporting and that of other organisations.

Work done

We are required to plan and perform our work in order to consider the risk of material misstatement of the efficacy statements. A material misstatement would be an efficacy statement that does not reflect the study design and quality of underlying research or the omission of key information from a relevant study.

In doing so, we:

- made enquiries of relevant Pearson management;
- evaluated the design of the Framework including key structures, systems, processes and controls for managing, generating and reporting the efficacy statements;
- tested all 19 controls across the 8 stages of the Framework;
- confirmed that all management reviews were performed by at least two members of Pearson's Efficacy & Research team;
- performed substantive testing on a sample basis of the data that underpins the research studies and the resulting efficacy statements, and the controls over the completeness and accuracy of that data (supported by Pearson Internal Audit in those instances where student data was subject to confidentiality restrictions);
- assessed the quality and conclusions of the underlying research studies;
- inspected the statistical analysis to assess whether the efficacy statements are valid, supportable and consistent with the underlying research studies;
- independently re-performed screening of relevant external public research studies and compared to that done by Pearson;
- assessed the efficacy statements and underlying Technical Report(s) for consistency with the Framework; and
- reviewed the product's efficacy web page, Research Report, and Technical Report(s) for alignment of research studies and efficacy statements.

Pearson responsibilities

The directors of Pearson are responsible for:

- designing, implementing and maintaining internal controls over information relevant to the preparation of efficacy statements that are free from material misstatement, whether due to fraud or error;
- establishing an objective framework for preparing and reporting efficacy statements;
- preparing and reporting efficacy statements in accordance with the Framework; and
- the overall content of the Framework and the Research Report.

Our responsibilities

We are responsible for:

- planning and performing the engagement to obtain limited assurance about whether the efficacy statements are free from material misstatement, whether due to fraud or error;
- forming an independent conclusion, based on the procedures we have performed and the evidence we have obtained; and
- reporting our conclusion to the directors of Pearson.

Inherent limitations

Efficacy research, and the resulting efficacy statements, reflect the implementation and use of a product in a particular context. It would not be appropriate to assume a product would always generate similar outcomes in other contexts and/or in the future.

Intended users and purpose

This report, including our conclusions, has been prepared solely for the board of directors of Pearson in accordance with the agreement between us, to assist the directors in reporting Pearson Mastering Chemistry efficacy statements, in accordance with the agreement between us dated 9 August 2017. We permit this report to be disclosed online[i] at https://www.pearson.com/corporate/efficacy-and-research/efficacy-reports in respect of the Mastering Chemistry Research Report to assist the directors in responding to their governance responsibilities by obtaining an independent assurance report in connection with the efficacy statements. To the fullest extent permitted by law, we do not accept or assume responsibility to anyone other than the board of directors and Pearson for our work or this report except where terms are expressly agreed between us in writing.

PricewaterhouseCoopers LLP

PricewaterhouseCoopers LLP
Chartered Accountants
London
3 April 2018

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i The maintenance and integrity of Pearson's website is the responsibility of the directors; the work carried out by us does not involve consideration of these matters and, accordingly, we accept no responsibility for any changes that may have occurred to the reported efficacy statements or the Framework when presented on Pearson's website.