



Pearson

Mastering Physics

Efficacy Research Report

April 3 2018



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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 20 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.

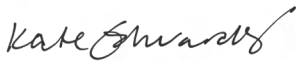
The journey ahead

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 Physics, an online tutorial system used in higher education introductory physics courses, is related to students' results in exams and external standardized tests.

This Research Report presents findings from two research studies we conducted with Penn State University, a school known for academic research in science: one correlational study with students enrolled in an introductory physics course, Phys 211; and one correlational study with students enrolled in Phys 212 after completing Phys 211 the previous semester. Our aim in using correlational study designs was to seek out possible relationships between the use of Mastering Physics 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 with students enrolled Phys 211, Pearson found that:

- A 10% increase in Mastering Physics homework grades is linked to a 4% increase in exam scores.
- A 10% increase in Mastering Physics homework grades is linked to a 2% increase in FCI¹ gains.

In the context of the study conducted with students enrolled in Phys 212 after completing Phys 211 the previous semester, Pearson found that:

- A 10% increase in Mastering Physics homework grades is linked to a 4% increase in exam scores.
- A 10% increase in Mastering Physics homework grades is linked to a 3% increase in BEMA² post-test scores.
- Requesting an additional 50 hints on homework assignments is associated with an increase in average exam scores of 2 percentage points.
- Requesting an additional 50 hints on homework assignments is associated with an increase in students' BEMA post-test scores of 3 percentage points.

The complete statements are set out in the boxes titled "Efficacy statements" on pages 13 and 16. These statements have been subject to assurance by PwC, whose report can be found at the end of the Research Report.

¹ Force Concepts Inventory

² Brief Electricity and Magnetism Assessment

Product design and development

Product overview

Mastering Physics is an online tutorial system designed to help students achieve mastery of core physics knowledge and concepts and develop domain-specific, physics problem-solving skills such as quantitative reasoning. It is a further development of Cybertutor, an early tutorial system for physics 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 Physics is designed to accompany a number of textbooks written in the physics discipline.

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

- Student engagement and learning experiences
- Critical reasoning and problem solving skills that can be applied to everyday applications and later courses
- Student achievement — e.g., in homework assignments, end of course examination results and external assessments, such as the Brief Electricity and Magnetism Assessment (BEMA) and Force Concepts Inventory (FCI) test

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 Physics is an online tutorial system designed to support students as they learn physics 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).

The design of Mastering Physics incorporates numerous principles from learning science, with the goal of helping all students achieve mastery of core physics knowledge and skills. The course management, gradebook and analytics features enable educators to assign homework throughout their course, and to remediate students' misunderstandings in real time and at scale. Pressure on time and resources means this would not otherwise be possible.

What follows is a summary of some specific learning science research that underpins the design of Mastering Physics.

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 Physics 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 Physics, 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 Physics users additional graded practice in areas in which they are still struggling. These homework assignments are dynamically created by Mastering Physics, 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 Physics features described above aim to enhance achievement.

Active, constructive, and interactive learning

Mastering Physics 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 students' 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 Physics generally supports students 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 Physics encourages constructive learning is with simulations. Simulations require students to apply their learning by critically evaluating information, deciding on next steps to take, predicting the outcomes of demonstrations, and solving novel problems. This feature aims to develop critical reasoning and problem solving skills.

Direct Measurement Videos — short videos of real events that allow students to explore physical phenomena — are designed to help students learn and apply physics concepts. Grids, rulers, and frame-counters appear as overlays on the video, enabling students to make precise measurements of quantities such as position and time. Students then apply these quantities along with physics concepts to solve problems and answer questions about the motion of the objects in the video.

Many Mastering Physics 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 so 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 Physics, 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 Physics 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 & Rawon, 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 Physics 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 Physics 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 have shown that feedback that explains or otherwise elaborates on the correctness of a response is more effective than feedback that indicates only correctness (Van der Kleij, Feskens, & Eggen, 2015).

Research on feedback timing (i.e., immediate vs. delayed) has produced a wide range of results, but findings generally indicate that immediate feedback improves learning of procedural skills (Shute, 2008), which are central to solving basic physics problems.

Mastering Physics 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 Physics

The Mastering product line, of which Mastering Physics 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 Physics has been used by over 4 million students in introductory physics courses. Earlier versions under the names of CyberTutor and MasteringPhysics have evolved into the current product.

Mastering Physics is currently used by 495,000 students per year at Higher Education level. The platform serves students from the United States, Canada, UK, South America and Europe.

Intended product implementation

Overview of intended product implementation

We aim to keep Mastering Physics flexible enough to allow our customers to make their own choices on how they want to implement it, and to allow them to tweak their practice over time to improve the experience and outcomes.

Customers have told us that they have a greater chance of impacting on learning when Mastering Physics 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 students are better prepared for assessments that don't use them)

Product research

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

Specifically, the activities in Mastering Physics 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 that students' usage of, and performance in, Mastering Physics correlates with achievement on independently administered course exams and standardized tests.

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 Physics 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 Physics 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 91 studies. After an initial review we found that four contained information relevant to Mastering Physics. 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 Physics 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 Pearson, that form the basis of the Efficacy Report for Mastering Physics. The research questions and findings are set out in detail below, including the efficacy statements generated by those studies.

Study 1

Study citation	A study of two semesters of an introductory, prerequisite physics course at Penn State University (March 2018) Pearson Global Product Organization, Efficacy & Research — Impact Evaluation
Research study contributors	Christine Leow, Kenneth Lee, and Yun Jin Rho (in collaboration with the instructors at Penn State University)
Research questions	<ol style="list-style-type: none">1. Why do some students have higher achievement — as measured by higher average exam scores and Force Concept Inventory (FCI) test scores — in the course than others? What is the contribution that the following factors make to students achieving a higher grade in the course?<ul style="list-style-type: none">— First generation college status— Gender— Prior achievement (as measured by ALEKS)— Mastering Physics usage patterns (e.g., amount of time spent, progress in homework assignments, use of hints)2. How does students' participation in the course, besides use of Mastering Physics, affect their achievement? What is the association between Mastering Physics usage and achievement while taking into account participation in other course components?
Related intended outcomes category	Standard of achievement or level of competence
Study design	Relational (correlational, not predictive) This study examined the association between the use of Mastering Physics for homework assignments and students' achievement on their course exams and the Force Concept Inventory (FCI) test during the first semester physics course (Phys 211—General Physics Mechanics). The FCI is a widely accepted standardized test that measures a student's mastery of concepts commonly taught during the first semester of physics. The textbook used in this course was <i>Scientists and Engineers: A Strategic Approach</i> , 3rd edition by Randall D. Knight.

Metrics studied	<ul style="list-style-type: none"> — Mastering Physics homework grades — Hints requested in Mastering Physics homework assignments — Total time spent using the product — Exam scores — FCI gains
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Description of sample	<p>This study is limited to participants at one school: Penn State University. Penn State University is known for academic research in science as well as educational research throughout its physical science departments.</p> <p>The study sample included students who were enrolled in the Fall 2015 and Fall 2016 semesters in the first introductory physics course. Only students who agreed to participate and for whom data were available were included in the study.</p> <p>This physics course, a calculus-based introduction to classical mechanics, is an important prerequisite course for later coursework in science and engineering disciplines. Students were non-physics majors. Two instructors taught the three classes in Fall 2015, while one instructor taught all three classes in Fall 2016, with almost 900 students enrolled in each semester (though only 600 students participated in the study). All instructors used Mastering Physics for homework assignments.</p> <p>As there are many ways to implement Mastering Physics, it is important to note that in both courses at Penn State University:</p> <ul style="list-style-type: none"> — There was a strong emphasis placed on homework as practice—not homework as summative assessment — All hints were free (no penalties or rewards)
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Sample size	<p>The full sample included approximately 1,800 students. However, of these, only approximately 1,200 students agreed to participate.</p> <p>After students who were missing data on prior achievement, exam scores, or FCI scores were dropped, the final analytic sample (when exam score was the outcome examined) was 1,114 students. When FCI gain score was the outcome examined, the final analytic sample was 961 students.</p>
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Analysis	<p>Hierarchical Linear Modeling (HLM) was conducted to assess the relationship between Mastering Physics use and students' achievement on the course exams and the FCI test.</p> <p>This method was chosen because it can account for nesting that occurs due to the nature of the sample; that is, individual students were nested within the same class for Fall 2015 and Fall 2016 (Raudenbush & Bryk, 2002). HLM addresses the issue that students within a class are more dependent on each other in their learning than they are with students taking the course in another semester. Most conventional statistical methods assume the independence of the analysis units, which is not the case in our study.</p> <p>It should also be noted that different instructors taught the two semesters, but unfortunately, data was not collected on the instructors to account for their differences. Hence, in the analysis, we were not able to separate the effects of the different classes in the different semesters from the different instructors.</p> <p>We wanted to answer the question: what is the association between use of Mastering Physics for homework assignments and achievement? — while controlling for participation in other course components (i.e., lecture and teaching assistant-led activities). Therefore, we also included participation in these other course components in our analyses. Participation was measured by the grades given by the instructor for participating in these course components.</p>
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Results

Students' average scores on Mastering Physics homework assignments were positively and significantly related to their average exam scores in the first introductory physics course in Fall 2015 and Fall 2016.

Students' average scores in Mastering Physics were also related to FCI gains.

Total time spent using Mastering Physics, on the other hand, was not significantly associated with exam scores although total time spent was significantly associated with FCI gains. These findings should be viewed with caution since the, time spent, variable does not differentiate between actively engaged and idle time. Some students might not have been actively engaged for the entire time they were logged in.

We also found no significant relationship between the number of hints students requested and their course performance.

Efficacy statements

In the context of this study, conducted at Penn State University for students enrolled in Phys 211, Pearson is able to make the following relational (correlational, not predictive) statements about the efficacy of Mastering Physics:

- A 10% increase in Mastering Physics homework grades is linked to a 4% increase in exam scores.
- A 10% increase in Mastering Physics homework grades is linked to a 2% increase in FCI gains.

It should be noted that these statements reflect a relationship between Mastering Physics 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 Physics to course performance once prior achievement has already been accounted for.

Limitations and generalizability

Time logged in does not mean actively engaged:

Although average homework assignment scores were statistically significantly associated with average exam scores, the total time spent in Mastering Physics was not found to be significantly related to average exam scores. This may be because some students spent time logged in but not actively engaged. The available data only reveals total time spent logged into the platform, without distinguishing between active time and idle time (logged in but away from the screen or doing other things).

Results are correlational and not causal:

Our study design does not allow us to determine whether higher achievement in Mastering Physics homework assignments would actually lead students to improve their achievement in their course exams and FCI or whether another factor is at play. We are, therefore, not able to rule out the influence of all the confounding factors on students' achievement in the course. To assess how Mastering Physics performance and usage behavior causes changes in learner outcomes, a more rigorous experimental study design would be needed.

The generalizability of the study:

The study made use of data at only one school for a specific physics 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	<p>Future research 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 research could also examine student engagement and learning experience in Mastering Physics and more detailed aspects of students' use of Mastering Physics, such as the number of solution checks requested by students while completing homework assignments. This could allow us to test more specific hypotheses about the relationships between students' use of Mastering Physics and problem-solving skills and achievement.</p> <p>Future research could also make use of more rigorous research designs. For example, an experimental or quasi-experimental research design could assess whether use of Mastering Physics leads to higher course performance — that is, whether the relationship we observed is causal in nature.</p>
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Read about this research in more detail in our [Technical Report](#)

Study 2

Study citation	A longitudinal study: student achievement in their second introductory physics course at Penn State University (March 2018), Pearson Global Product Organization, Efficacy & Research — Impact Evaluation.
Research study contributors	Christine Leow, Kenneth Lee and Yun Jin Rho (in collaboration with the instructors at the institution who provided the study data)
Research questions	<ol style="list-style-type: none"> Why do some students have higher achievement — as measured by higher average exam scores and Brief Electricity and Magnetism Assessment (BEMA) scores — in the second semester physics course than others? What is the contribution that the following factors make to students achieving a higher grade in the course? <ul style="list-style-type: none"> — Prior ability (i.e., general ability as measured by ALEKS prior to enrollment in both physics courses) — Prior achievement (i.e., more specific abilities needed for the physics courses as measured by the average exam scores in the Fall 2015 course) — Mastering Physics usage patterns in the second semester physics course (e.g., amount of time spent, progress in homework assignments, use of hints) How does students' participation in the second semester physics course, besides use of Mastering Physics, affect their achievement? What is the association between Mastering Physics and achievement while taking into account participation in other course components such as lectures and teaching assistant led activities?
Related intended outcomes category	Standard of achievement or level of competence
Study design	<p>Relational (correlational [longitudinal], not predictive)</p> <p>This study examined the association between the use of Mastering Physics for homework assignments and students' achievement on their course exams and BEMA during the second semester physics course (Phys 212 Electricity and Magnetism). The textbook for this course was <i>Scientists and Engineers: A Strategic Approach</i>, 3rd edition by Randall D. Knight.</p>
Metrics studied	<ul style="list-style-type: none"> — Mastering Physics homework grades — Hints requested in Mastering Physics homework assignments — Total time spent using the product — Exam scores — BEMA post-test scores

Description of sample	<p>This study is limited to participants at one school: Penn State University. Penn State University is known for academic research in science, as well as educational research throughout its physical science departments.</p> <p>All the students in this study were non-physics majors enrolled in the first year physics course in Fall 2015 (Phys 211—General Physics Mechanics) and moved on to the second physics course in Spring 2016 (Phys 212 Electricity and Magnetism) at Penn State University. This sample constituted 64% of the students originally enrolled in the first physics course.</p> <p>As there are many ways to implement Mastering Physics, it is important to note that in both courses at Penn State University:</p> <ul style="list-style-type: none">— There was a strong emphasis placed on homework as practice — not homework as summative assessment— All hints were free (no penalties or rewards)
Sample size	<p>The total sample comprised 397 students.</p> <p>Due to missing data, the final analytic samples included 374 students when analysing exam scores, and 350 students when BEMA scores was the outcome examined.</p>
Analysis	<p>Ordinary least squares (OLS) regression analysis was conducted to assess the relationship between Mastering Physics use and student achievement on the course exams and BEMA. This method was chosen to account for prior physics achievement, as measured by average exam scores from the first introductory physics course in the sequence and prior general ability of the students, as these were confounding factors that could influence student achievement in the course.</p> <p>We wanted to answer the question: what is the association between use of Mastering Physics and course achievement while controlling for participation in other course components (i.e. lecture and teaching assistant? — led activities). Therefore, we also included participation in these other course components in our analyses. Participation was measured by the grades given by the instructor for participating in these course components.</p>
Results	<p>Students' average score on Mastering Physics homework assignments was positively and significantly related to the average exam scores in Spring 2016.</p> <p>The average score on Mastering Physics homework assignments was also positively and significantly linked to achievement in BEMA post-test scores.</p> <p>The number of hints requested by students was positively and significantly associated with both exam scores and BEMA post-test scores.</p> <p>However, total time spent was found to be marginally and negatively related to average exam scores and it was not significantly related to BEMA post-test scores. Since it was not possible to differentiate between the time that students spent actively engaged when logged in to Mastering Physics and the time when they were not actively engaged when logged in, the findings on, time spent, should be viewed with caution.</p>

Efficacy statements

In the context of this study, conducted at Penn State University for students enrolled in Phys 212 after completing Phys 211 the prior semester, Pearson is able to make the following relational (correlational, not predictive) statements about the efficacy of Mastering Physics:

- A 10% increase in Mastering Physics homework grades is linked to a 4% increase in exam scores.
- A 10% increase in Mastering Physics homework grades is linked to a 3% increase in BEMA post-test scores.
- Requesting an additional 50 hints on homework assignments is associated with an increase in average exam scores of 2 percentage points.
- Requesting an additional 50 hints on homework assignments is associated with an increase in students' BEMA post-test scores of 3 percentage points.

It should be noted that these statements reflect a relationship between Mastering Physics 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 were calculated across all students in the sample and capture the contribution of Mastering Physics to course performance once prior achievement has already been accounted for.

Limitations and generalizability

Time logged in does not mean actively engaged:

Although average homework assignment scores and requests for hints were statistically significantly associated with average exam scores, the total time spent in Mastering Physics was not found to be significantly related to average exam scores. This may be because some students spent time logged in but not actively engaged. The available data only reveals total time spent logged into the platform, without distinguishing between active time and idle time (logged in but away from the screen or doing other things).

Results are correlational and not causal:

Our study design does not allow us to determine whether higher achievement in Mastering Physics homework assignments would actually lead students to improve their achievement in their course exams and BEMA, or whether another factor is at play. We are not able to rule out the influence of all confounding factors on students' achievement in the course.

The generalizability of the study:

The study made use of data at only one school for a specific physics 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 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 research could also examine student engagement and learning experience in Mastering Physics, and more detailed aspects of students' learning behaviors. For example, the number of hints that students requested while completing homework was found to be significantly and positively related to their exam scores in the second semester Physics course, but not the first. Follow up studies could allow us to identify the settings and conditions under which hint opening and other learning behaviors are associated with better problem-solving skills and higher achievement.

Future research could also make use of more rigorous research designs. For example, an experimental or quasi-experimental research design could assess whether use of Mastering Physics leads to higher course performance — that is, whether the relationship we observed is causal in nature.

Read about this research in more detail in our [Technical Report](#)

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Appendix: 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 Physics is designed to be accessed remotely and on any device, allowing students to access learning materials from anywhere, at any time.

Intended outcome 2

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

Mastering Physics is designed to be accessible after a simple registration process. After registration, students are able to log in on any device and see their assignments in both a list view and a calendar view.

Intended outcome 3

Learners can access the learning content/subject matter.

Mastering Physics 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 Physics 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.

All of the resources in Mastering Physics are intended to support students to persist to completion of individual assignments and of the course as a whole.

Intended outcome 6

Learners complete the course first time.

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

Intended outcome 7

Learners attend class.

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

Intended outcome 8

Learners complete assignments.

Mastering Physics students 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 assignments on time.

Outcomes related to standard of achievement or level of competence

We have evidence related to this category of intended outcomes for Mastering Physics. Find it under "Product Research".

Intended outcome 9

Learners pass the physics course first time taking the course.

Mastering Physics is designed to help students improve their knowledge of physics. Relevant, thoughtful activities keep students engaged with the content, and immediate feedback and hints support students as they learn. Adaptive Follow Up assignments provide additional practice, personalized for the specific concepts and skills a given student struggles with.

Intended outcome 10

Learners pass assignments in Mastering Physics.

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

Intended outcome 11

Learners pass the external exam.

Students using Mastering Physics 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 12

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

Mastering Physics 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 13

Learners progress/choose next level physics courses from Phy 1 to Phy 2.

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

Intended outcome 14

Learners progress to next level engineering courses.

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

Intended outcome 15

Learners demonstrate increased performance in courses after algebra and calculus based physics.

In addition to completing the physics course, Mastering Physics 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 Physics 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 Physics 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 Physics 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 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 Physics efficacy statements, in accordance with the agreement between us dated 9 August 2017. We permit this report to be disclosed onlineⁱ at <https://www.pearson.com/corporate/efficacy-and-research/efficacy-reports> in respect of the Mastering Physics 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
Chartered Accountants
London
3 April 2018

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.



Pearson