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Technical Report

A longitudinal study: Student achievement in their second introductory physics course at Penn State University

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Executive Summary

Overview of Mastering Physics

This study investigates the effectiveness of Mastering Physics, an intelligent online tutorial, homework, and assessment tool for higher education physics instruction. Mastering Physics provides instructional videos, interactive simulations from the PhET Group at the University of Colorado, and a large collection of physics problems that can be assembled into quizzes and homework assignments. These problems come in many forms, from multiple-choice questions testing knowledge of basic concepts to open-ended questions requiring students to apply concepts and equations to solve complex, multi-part problems. Many problems are accompanied by some combination of video demonstrations, simulations, and optional hints, and all provide immediate feedback that addresses students' specific responses.

Retention in Science, Technology, Engineering, and Math

Despite a large number of students entering college to major in science, technology, engineering, and math (STEM) fields, reports suggest that STEM positions in both industry and the government sectors remain hard to fill (Bureau of Labor Statistics, May 2015). Studies indicate that as many as 40 percent of students intending to major in science or engineering eventually either select a different major or drop out of college. Although a number of factors are likely at work, one reason presented is the difficulty of STEM courses that often lack adequate supports for students struggling with their coursework (Drew, November 2011). Mastering Physics addresses these issues by providing an on-line learning environment rich in support to learners, setting them up for successful completion of their physics course. This study sought to determine the relationship between the use of Mastering Physics and students' learning in the second physics course after considering their prior achievement in the first physics course.

Intended outcomes and study sample

In order to determine if and how students are learning in their second introductory physics course, this study examined two outcome measures that would give a valid and unbiased indication of their achievement in the course. One measure is the average exam score that students received in the second course. Another is derived from the Brief Electricity and Magnetism Assessment (BEMA), which is designed to assess students' understanding of basic electricity and magnetism concepts covered in college-level calculus-based introductory physics courses. The test was evaluated and found to be reliable (Ding, Chabay, Sherwood, & Beichner, 2006). In this study, it was given to the students in the second physics course. We focused on the BEMA administered at the end of the semester, since the instructor reported that the students did not know enough about the questions in BEMA at the beginning of the semester.

The participants in the study were students enrolled in two sequential introductory physics courses at Penn State University for Fall 2015 and Spring 2016. 64% of the students (n=397) who enrolled in the first physics course in Fall 2015 continued to the second physics course in Spring 2016. Other students in the Spring 2016 class either took the first course prior to Fall 2015 or were transferred from another institution. The first physics course was a prerequisite for the second. Two instructors taught the two introductory physics courses; both used Mastering Physics for homework assignments. This study mostly focused on the students who continued from Fall 2015 to Spring 2016.

Research questions

The primary goal of this study was to assess the relationship between use of Mastering Physics (as determined by total hints requested by students in Mastering Physics and their scores in Mastering Physics homework assignments) and student learning (as measured by their achievement on the second physics course's exams and BEMA). The following specific questions were examined in this study.

1. Why do some students have a higher achievement (as measured by higher average exam scores and BEMA scores) in the second physics course than others? What is the contribution that the following factors make to students achieving a higher grade in the course?
    a. prior ability, as measured by Assessment in Learning and Knowledge Spaces (ALEKS) prior to enrollment in both physics courses
    b. prior achievement (more specific abilities needed for the physics courses as measured by the average exam scores in the Fall 2015 course)
    c. Mastering Physics usage patterns in the second physics course (for example, amount of time spent, progress in homework assignments, use of hints)
2. How does students' participation in the second 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?

Key findings

Based on the regression results and using the sample of students who continued from Fall 2015 to Spring 2016, we found prior ability (as measured by ALEKS) and prior achievement (as measured by average exam scores in the first physics course) were significantly related to achievement. In addition, we also found positive and significant relationship between the platform variables and the achievement outcomes.

The following claims about platform variables and achievement can be made and the diagram below depicts these claims visually:

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

Table 1: Visual representation of the claims about the platform variables and achievement

Mastering Physics Platform Variable	**Achievement Outcome Measure**	
	Average Exam Score	**BEMA Score**
Average Score on Homework Assignments	Effect Size = 0.29	Effect Size = 0.20
Total Number of Hints Requested	Effect Size = 0.11	Effect Size = 0.21
Significant positive association, higher values for platform variable associated significantly with higher scores on the achievement outcome measure.		

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Significant negative association, higher values for platform variable associated significantly with lower scores on the achievement outcome measure.

No significant association, platform variable not associated with scores on the achievement outcome measure.

Limitations

This study has a number of limitations. First, the research design allows us to make only correlational claims and not causal claims about the use of Mastering Physics and achievement. We therefore cannot know whether higher achievement in Mastering Physics homework assignments would actually lead students to improve their achievement in their course exams and BEMA. It could be that another factor worked alongside the use of Mastering Physics that led to the higher achievement. Our study can only speak to an association and not a causal claim about use of Mastering Physics and achievement.

Though we are able to control for some confounding student variables that can affect student achievement, we are not able to rule out the influence of all possible confounding factors on students' achievement in the course. However, it is important to note that we were able to control for crucial variables that have been found to be strongly related to achievement – prior ability, as measured by ALEKS, as well as prior achievement, as measured by average exam scores in the first physics course. What Works Clearinghouse (2012) considers prior achievement (or prior ability) and socio-economic status (as measured by first generation college status) as the two most crucial variables in higher education research that need to be accounted for. No first generation college status students were enrolled in the second physics course. Thus, prior achievement (or prior ability) was our only crucial type of variable. Being able to address this type of variable pointed to the validity of the relational claims we are making in this study.

Additionally, the study made use of data from two sequential physics courses taught by two instructors at a single school in Fall 2015 and Spring 2016 only. So the extent of generalizability of the findings from this study might be another limitation.

Recommendations and next steps

The findings from this study are only the start towards understanding how the use of Mastering Physics is associated with student achievement. One direction for future research suggested by the findings of this study is to examine whether other types of interactions can affect student achievement. In the analyses, we examined only the number of hints used and time spent in Mastering Physics, in addition to the average score that the student obtained for the homework assignments given by the instructor in the second physics course. A limitation of the time spent variable is that we were not able to differentiate between the time when students were actively engaged while logged into Mastering Physics, and the time when students were logged in but not engaged. Other types of interactions in Mastering Physics could be more accurate measures of students' level of engagement in the tool, such as the number of solution checks requested by students while completing homework assignments. Such data were, unfortunately, not available in our current study.

Further studies on Mastering Physics could also make use of more robust research methods. For example, they could use an experimental or quasi-experimental research design to allow for a causal examination of the relationships among variables – to assess whether a change in one platform variable causes a change in an achievement outcome measure. They could also focus on a larger sample across many schools and instructors so that the results would generalize more broadly. In this current study sample, there were no first generation college students enrolled in the physics courses, so the findings were not generalizable to these students. Finally, as suggested above, they could control for a wider array of student variables (such as students' obligations outside of class and their intended major) to more thoroughly adjust for confounding factors that might influence students' achievement in a physics course other than use of Mastering Physics.

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Introduction

Despite a large number of students entering college to major in science, technology, engineering, and math (STEM) fields, reports suggest that STEM positions in both industry and the government sectors remain hard to fill (Bureau of Labor Statistics, May 2015). Studies indicate that as many as 40% of students intending to major in science or engineering eventually either select a different major or drop out of college. Although a number of factors are likely at work, one reason presented is the difficulty of STEM courses that often lack adequate supports to students struggling with the coursework (Drew, November 2011). Mastering Physics addresses these issues by providing an online learning environment rich in support to learners, setting them up for successful completion of their physics course.

Background foundational research

The study presented here investigates the effectiveness of Mastering Physics, an intelligent online tutorial, homework, and assessment tool for higher education physics instruction. Mastering Physics provides instructional videos, interactive simulations from the PhET Group at the University of Colorado, and a large collection of physics problems that can be assembled into quizzes and homework assignments. These problems come in many forms, from multiple-choice questions testing knowledge of basic concepts to open-ended questions requiring students to apply concepts and equations to solve complex, multi-part problems. Many problems are accompanied by some combination of video demonstrations, simulations, and optional hints, and all provide immediate feedback that addresses students' specific responses.

Key features of the research into learning design for Mastering Physics

The design of Mastering Physics incorporates several principles from learning science in order to enhance learning and, by extension, performance on summative assessments like those examined here. We will now review several of these principles to establish why Mastering Physics use might be positively associated with summative assessment performance.

Retrieval practice

Recalling information from memory, often called *retrieval practice*, improves learning and memory more than simply reviewing that same information. This benefit of retrieval practice is commonly referred to as the *testing effect* and has been demonstrated in numerous laboratory and educational settings (Roediger & Karpicke, 2006). In the present study, students engaged in retrieval practice whenever they recalled information in order to complete homework problems. Additionally, the homework assignments allowed students to attempt problems multiple times; research indicates that such repeated retrieval practice further improves learning (Greene, 2008).

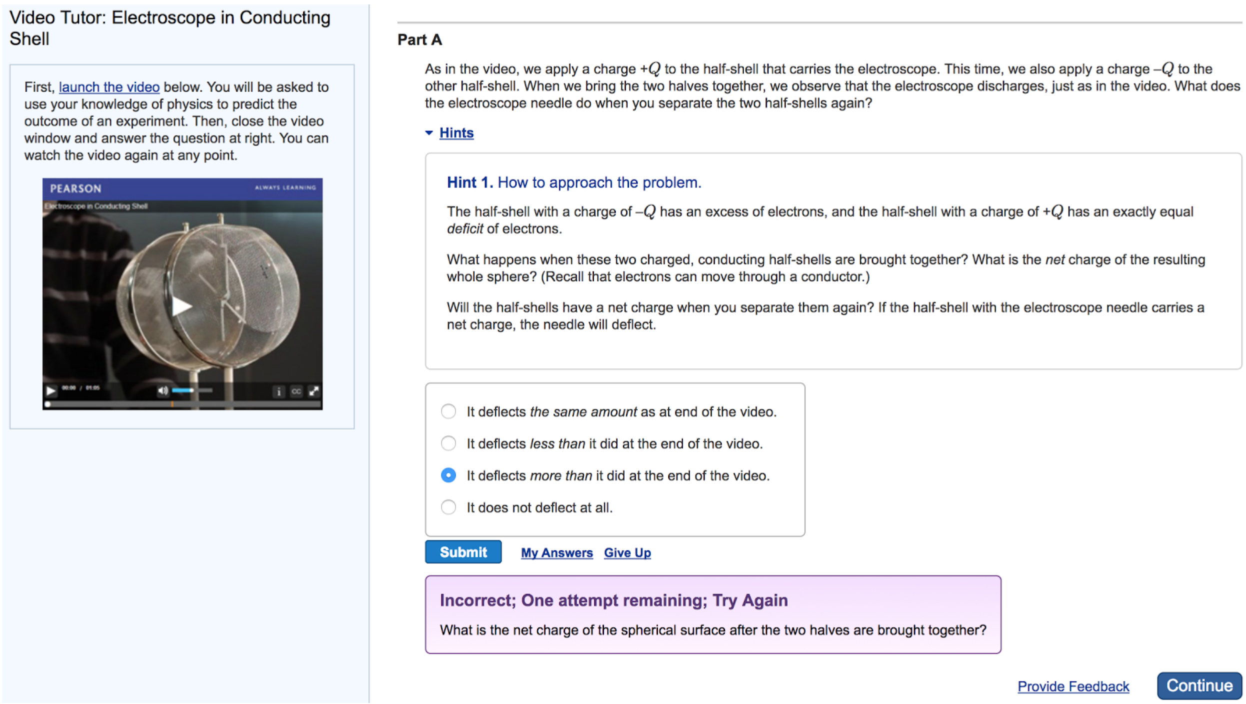
Scaffolding

As mentioned, many Mastering Physics problems provide optional hints that give students problem-solving guidance similar to the guidance they might receive from an instructor (see Figure 1 for an example). 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 or fail to achieve. Scaffolding can support learning by helping learners structure complex tasks and by highlighting aspects of problems that require special attention (Reiser, 2004).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.

Feedback

Learning is enhanced when learners are provided with regular feedback on their performance. Research on computer-based feedback systems have shown that feedback that explains or otherwise elaborates on a response is more effective than feedback that indicates only correctness (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 improves learning of procedural skills (Shute, 2008), which are central to solving basic physics problems. Mastering Physics provides students with immediate feedback on each homework problem. This either 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; see Figure 1 for an example).

Figure 1: A Mastering Physics homework problem



Note: The left panel provides a video demonstration that teaches a concept central to the problem by having the student predict the outcome of a simple experiment. An optional hint is revealed above the problem. An incorrect answer has been chosen, and the pink box immediately displays feedback specific to this incorrect response. When the correct response is chosen, a green box immediately displays feedback explaining why that response is correct.

Active, constructive, and interactive learning

The Mastering Physics problems and associated features more generally embody what are known as *active*, *constructive*, and *interactive* approaches to learning (Chi, 2009). Active learning refers to any learning activity involving more than passive intake of information, while constructive learning refers to activities in which a student produces some solution, idea, explanation, or other output that goes beyond previously encountered information. Interactive activities involve a back-and-forth interaction between the student and another person or, in the context of the present study, an intelligent tutoring system.

Mastering Physics homework problems generally support active learning by requiring students to go beyond passive activities like reading a textbook or listening to a lecture. The problems support constructive learning by requiring students to predict outcomes of demonstrations, solve novel problems, or use interactive simulations to explore relationships between inputs and outputs of physical systems. Finally, Mastering Physics is interactive in that it provides students with hints and feedback that students can consider and respond to in order to enhance their learning and performance. Research demonstrates that each of these approaches to learning is more effective than passive approaches, with efficacy increasing when advancing from active to constructive to interactive activities (Chi, 2009).

Based on these principles, we expect that engagement with and performance in Mastering Physics should be associated with improved learning and higher scores on the two summative assessments analyzed here. Measures of engagement include students' time logged in and number of hints accessed, and performance is measured as average homework score. With clear benefits of scaffolding on learning, we hypothesize a positive association between number of hints accessed and summative assessment performance. Time logged in is a somewhat coarse measure of engagement, though it stands to reason that the longer students spend in Mastering Physics, the more opportunity they have to experience the benefits of retrieval practice, scaffolding, feedback, and active, constructive, and interactive learning. We therefore hypothesize that time logged in is positively associated with summative assessment performance. Finally, students who take advantage of hints and feedback in retrying homework problems they initially answered incorrectly should both experience greater learning and earn higher homework scores. We therefore hypothesize a positive association between homework and summative assessment scores.

The present study

The primary goal of this study was to assess the relationship between use of Mastering Physics, as determined by students' level of engagement with the tool, and student learning, as measured by their achievement on the course exams and Brief Electricity and Magnetism Assessment (BEMA). The latter is designed to assess students' understanding of basic electricity and magnetism concepts covered in college-level calculus-based introductory physics courses. The BEMA test was evaluated and found to be reliable (Ding, Chabay, Sherwood, & Beichner, 2006). This study focused on the achievement of students in their second physics course and on students who had continued their study from Fall 2015 to Spring 2016, when they were enrolled in the two sequential introductory physics courses at Penn State University.

Besides focusing on this goal, the study also explored whether student participation in other instructional components of the second physics course, such as lectures and teaching assistant led activities, affected their achievement in the course.

Specifically, this study addresses the following research questions:

1. Why do some students have a higher achievement (as measured by higher average exam scores and BEMA scores) in the second physics course than others? What is the contribution that the following factors make to students achieving a higher grade in the course?

   a. prior ability, as measured by Assessment in Learning and Knowledge Spaces (ALEKS) prior to enrollment in both physics courses
   b. prior achievement (more specific abilities needed for the physics courses, as measured by the average exam scores in the Fall 2015 course)
   c. Mastering Physics usage patterns in the second physics course (such as amount of time spent, progress in homework assignments, use of hints)
2. How does students' participation in the second 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?

A range of student factors is known to be associated with student achievement. Our study aimed to identify the unique contribution of Mastering Physics use to student achievement, independent of other confounding factors known to be related to student achievement. We therefore sought to collect data on and adjust (or statistically control) for extraneous factors that might affect student achievement in the second physics course, other than use of Mastering Physics. This was done to strengthen the quality of the study and to further support the validity of any claims we can make about the use of Mastering Physics.

Important confounding variables that we were able to control for in the analyses were prior general ability, as measured by ALEKS, and prior specific achievement, as measured by average exam scores in the first physics course. What Works Clearinghouse (2012) considers prior achievement (or prior ability) and socio-economic status (as measured by first generation college status) as the two most crucial variables in higher education research. Our study sample did not contain students who were first generation college status. Thus, prior achievement (or prior ability) was our only crucial type of variable. Controlling for this type of variable enabled us to strengthen the claim we can make about the use of Mastering Physics.

Our main hypothesis is that higher use of Mastering Physics, as reflected in students' greater level of engagement in the tool, will be linked to higher achievement on course exams and BEMA. The logic behind our hypothesis is that greater level of engagement in Mastering Physics can provide students with greater exposure to, and deeper processing of, physics content as they complete the homework assignments, resulting in improved student learning and higher achievement in course exams and BEMA.

In addition to the use of Mastering Physics for homework assignments, other course components might affect student achievement in the course. For example, the level of engagement in lectures and teaching assistant led activities would also affect students' achievement. In this study, we also examined how participation in these other course components might interact with the use of Mastering Physics to affect achievement in course exams and BEMA.

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Method

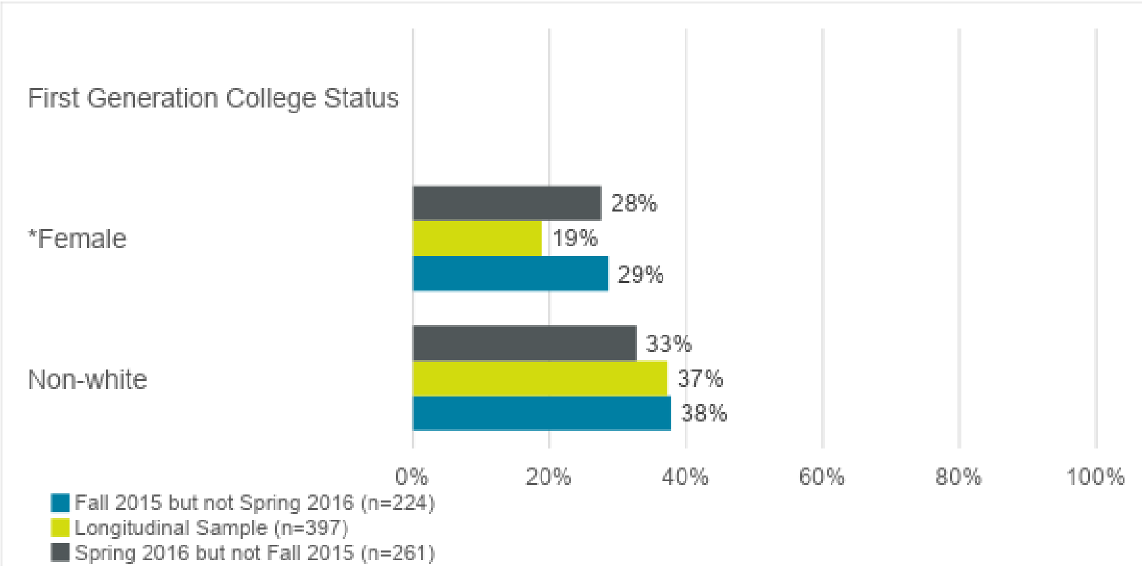
This study examined the association between the use of Mastering Physics in the second sequential physics course, and students' achievement on the course exams and BEMA, after controlling for confounding student characteristics that might affect achievement. Confounding student characteristics that were controlled for in the study included prior ability, as measured by ALEKS scores, and prior achievement, as measured by average exam scores in the first physics course.

Mastering Physics was used by both instructors in the two sequential physics courses for homework assignments. We measured students' Mastering Physics use in the second physics course by the number of hints made, the time spent, and the performance in homework assignments within Mastering Physics. Since students' achievement in the second course might be affected by course variables other than engagement in Mastering Physics, we also examined other course components, such as students' participation in lectures and teaching assistant led activities, and the potential interplay between these components, the use of Mastering Physics and students' achievement in the course.

Participants

This study took place at Penn State University during the Fall 2015 and Spring 2016 semesters, when the two sequential courses took place consecutively. These introductory physics courses for non-physics majors focused on calculus-based introduction to classical electricity and magnetism. Two instructors taught the courses. Some students went directly from the course in Fall 2015 to the course in Spring 2016. Other students who were enrolled in Spring 2016 either took the first physics course prior to Fall 2015 or were transfers. The first physics course was a required prerequisite course for enrollment in the second physics course. Figure 2 below shows the characteristics of the students who were enrolled in both the Fall 2015 and Spring 2016 courses (longitudinal sample). They were compared to students who were enrolled in either the Fall 2015 course or the Spring 2016 course but not both.

Figure 2: Baseline characteristics of students enrolled in Fall 2015 and/or Spring 2016



Note. Percentages of females are significantly different among the three groups ($p < .01$).

Data

This study took place as part of a collaboration between the instructors of the courses at Penn State University and Pearson. The instructors had collected various data on student characteristics, course grades, and BEMA scores for a prior study. Pearson then shared the platform data on Mastering Physics with the instructors, who de-identified all the data before sharing back with Pearson. Pearson then merged all the sources of data together. For details on the sample sizes that resulted from the data merge and the final analytic samples used for the analyses, please see Appendix A. Below is a description of the types of data that were available.

Student characteristics

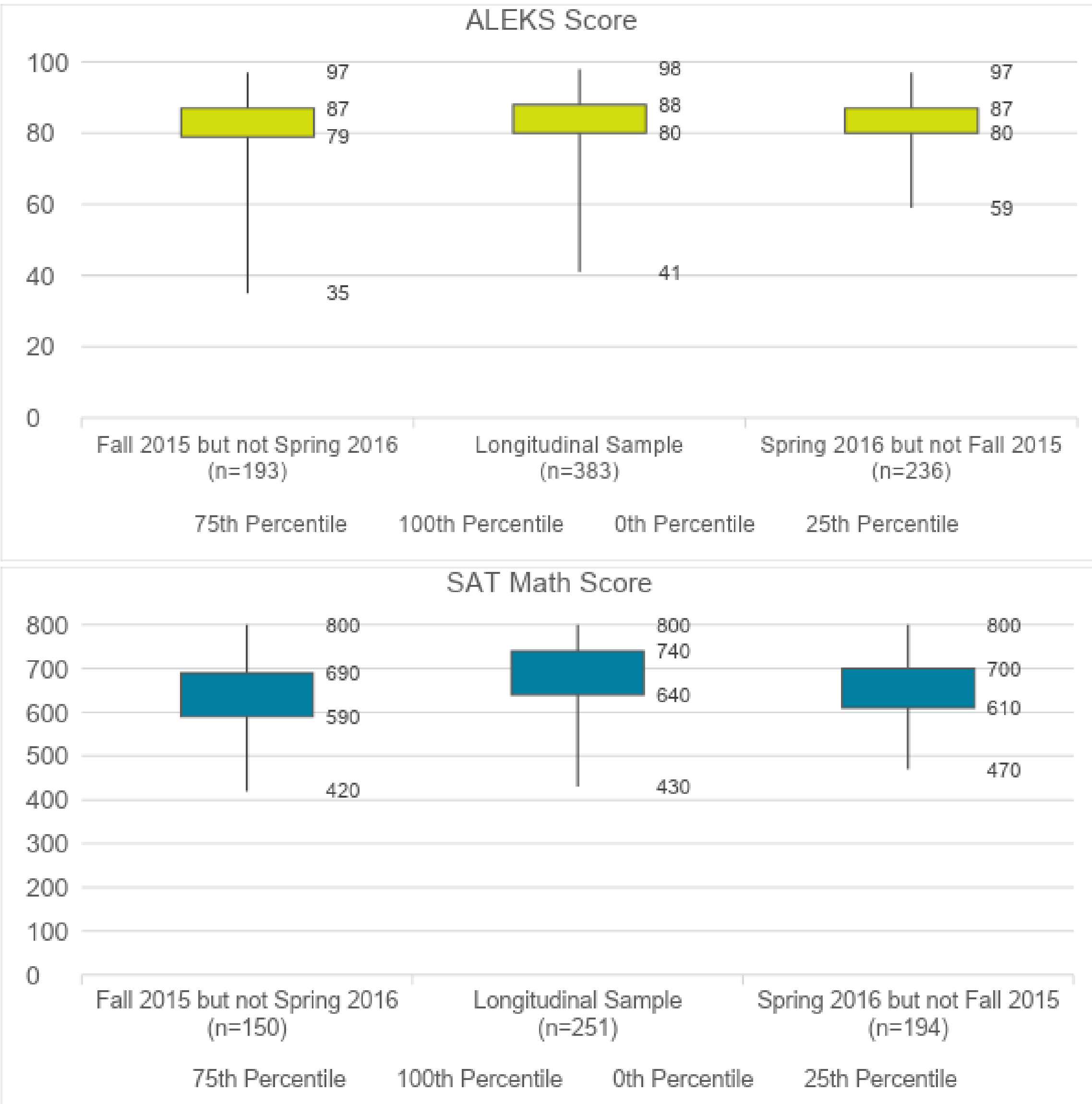
For this study, data were available for gender, ethnicity, and first generation college status. Given that there is generally a lack of females and minority ethnic groups enrolled in STEM courses, it is important for us to address these two student characteristics in our analysis. Though socio-economic status is an important confounding variable to consider and control for in the analysis, the study sample did not contain any students who were first generation college status, which is a proxy for socioeconomic status.

Prior general ability

ALEKS and SAT Math scores were also available. Either of these scores is a good measure of students' prior general ability, which is another important characteristic that we need to account and control for in the analysis. The amount of missing data for ALEKS was 3.5% while that for SAT Math was 37%.

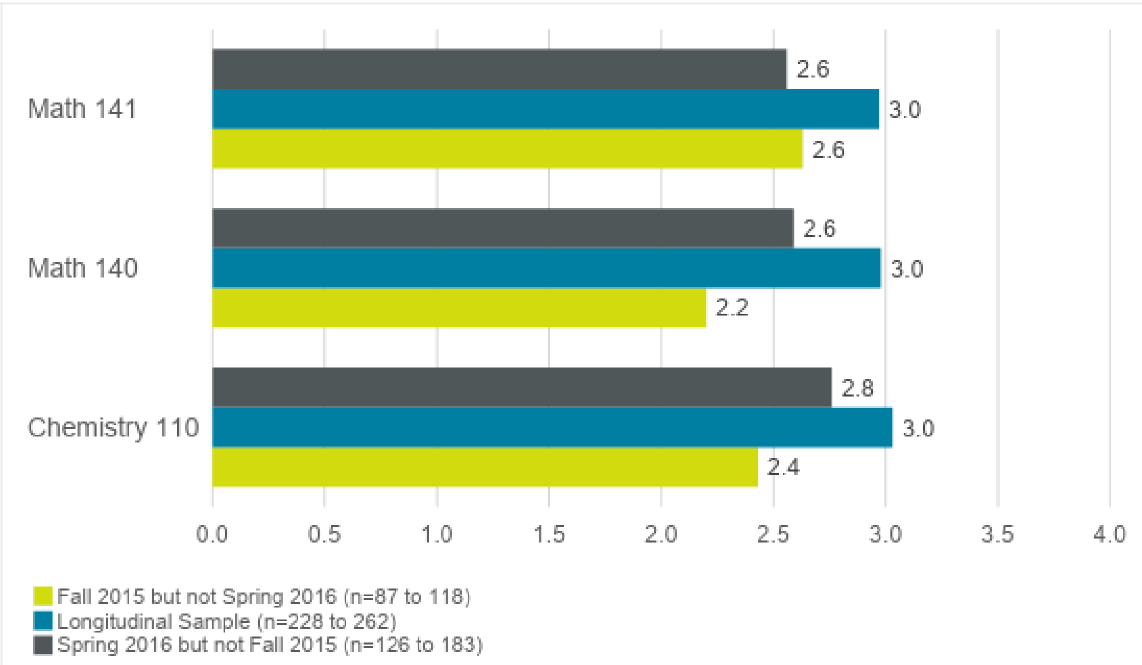
Hence, ALEK was chosen over SAT Math scores as a measure of prior general ability in the analysis. Figure 3 shows the ALEKS and SAT Math scores of students enrolled in the physics courses. There were also some prerequisite courses that students were required to complete before enrolling in the first physics course. Figure 4 shows performance in the prerequisite math and chemistry courses.

Figure 3: Prior ability at baseline for students enrolled in Fall 2015 and/or Spring 2016



Note. The means of ALEKS score are not significantly different among the three groups of students but means of the SAT Math score are significantly different (p < .0001).

Figure 4: Grade Point Average (GPA) for prerequisite courses to Physics 211 for students enrolled in Fall 2015 and/or Spring 2016



Note. The means of the GPAs are significantly different among the three groups of students across the three prerequisite courses ($p < .001$).

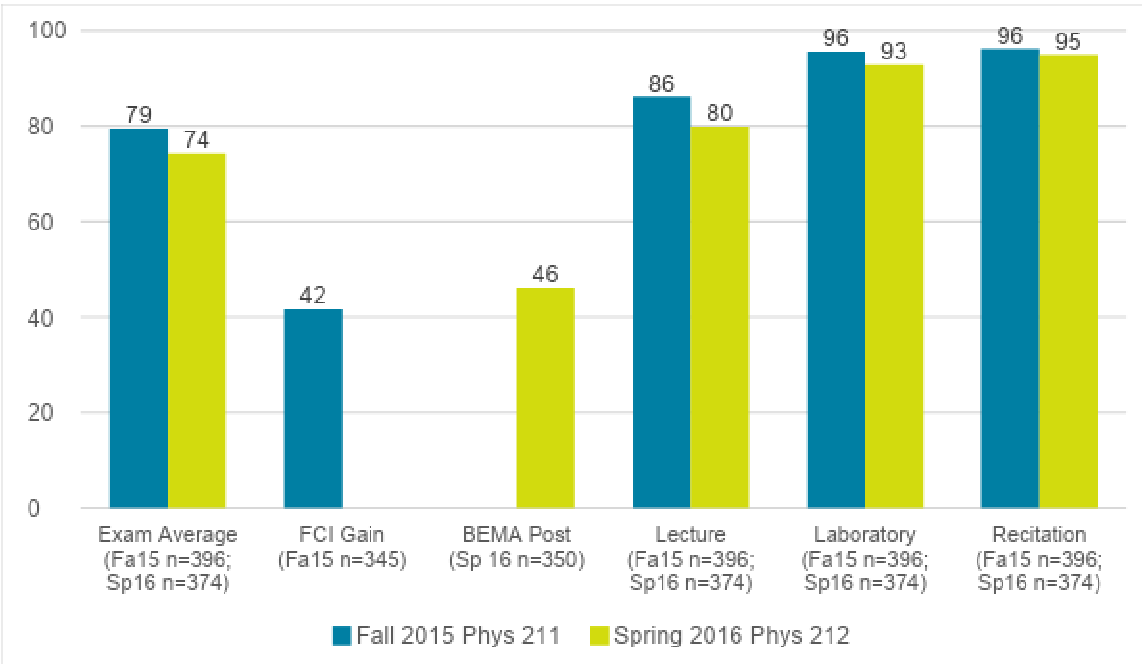
Course grades and BEMA

In this study, we examined students' achievement in the second physics course by focusing on their exam scores. Three exams were given in the second physics course; the average scores of these three exams were used as an outcome measure in this study. In addition, the BEMA administered by the instructor at the end of the semester was another outcome measure examined in this study. Though BEMA was given at the beginning (pre) and at the end of the semester (post), the instructor did not think that the students knew enough at the beginning of the semester, and hence the BEMA pre-test was not an accurate reflection of their knowledge.

Besides exam scores and BEMA post-test, students also received scores for various components of the second physics course. In this study, we used these scores as measures of the level of participation in the various course components. Specifically, two scores were considered – one for participation in lectures, and another for participation in recitations and laboratories, which are teaching assistant led activities. Clickers were used during the lectures for quizzes at the beginning of the class, for in-class concept questions, and for review of class materials. The lecture scores that students received were based largely on their clicker scores. Students met for recitations and laboratories once per week. These two activities were designed to provide hands-on experience with materials being investigated in the course, and allowed students to work collaboratively in three-member groups to complete problem-solving exercises. The scores students received for recitations and laboratories were averaged in this study for analysis.

Figure 5 below shows the scores that the students received for the various course components as well as their BEMA scores.

Figure 5: Grades for various course components as well as the FCI gain in Fall 2015 (Physics 211) and BEMA scores in Spring 2016 (Physics 212) for the longitudinal sample

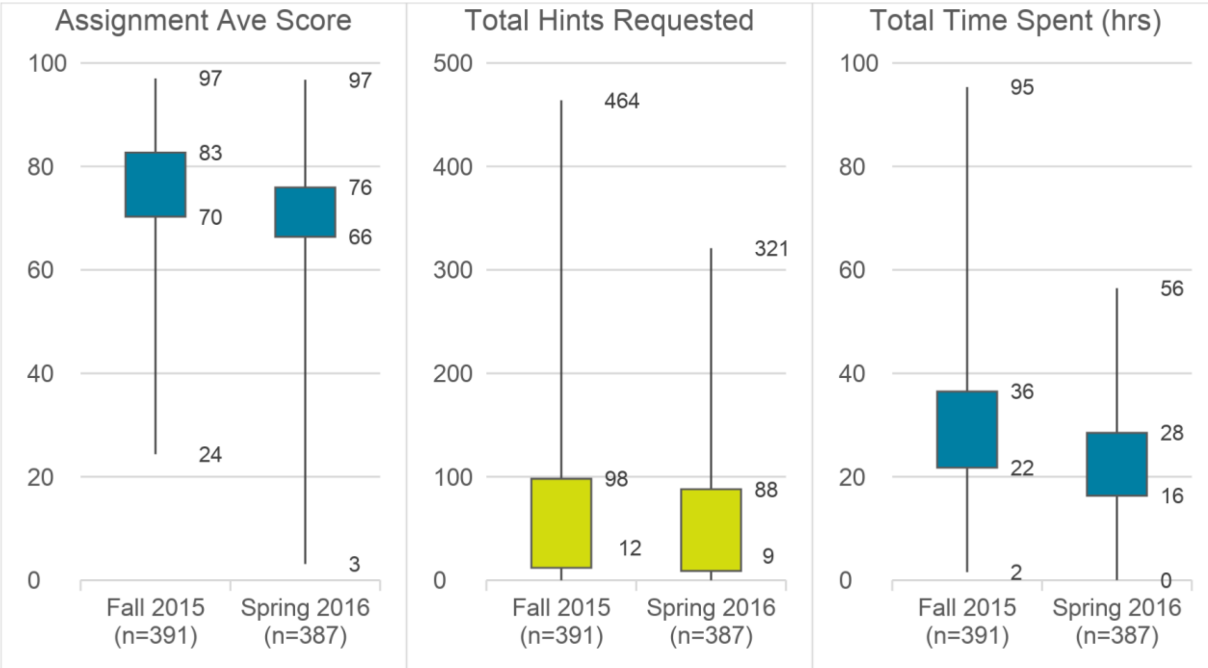


Note. The exam average, lecture, and laboratory scores were significantly lower in Spring 2016 than in Fall 2015 at $p < .05$.

Mastering Physics platform data

The instructors used Mastering Physics to assign homework for the physics courses. Platform data on Mastering Physics provided measures of both student performance on homework assignments and students' engagement within Mastering Physics. Students' level of engagement in Mastering Physics was measured by the total number of hints requested and the total time spent logged in to the tool. Figure 6 shows Mastering Physics use and the average score for homework assignments in both the Fall and Spring semesters for the longitudinal sample. Usage was found to be significantly lower in Spring 2016 than Fall 2015.

Figure 6: Platform use for longitudinal sample



Note. Across assignment average score, total hints, and total time spent, usage was significantly lower in Spring 2016 than Fall 2015 at $p < .05$.

Before proceeding further, we would like to add a note about the platform variables – platform average score and platform total time. The platform average score was derived by averaging the scores that students received for all assignments given by the instructors in the course. If the student did not have a score for that assignment in the platform data, the student would be assigned a score of 0, indicating that the student did not complete that assignment to get the needed score. Scores were given only for homework assignments submitted before the due date. In addition, the instructors gave the maximum score for homework when the students completed a certain number of homework assignments, thereby allowing the students to skip some homework assignments without penalty. In our analysis of platform average score, the average score across all homework assignments was considered, even when the students completed the threshold number of assignments. For those assignments that the students did not complete after they reached the threshold, the assignments that were not completed were given a score of 0. Hence our platform average score also reflected the motivation of the students when they completed more homework assignments beyond the required threshold.

Total platform time reflected the time that the students were logged in to Mastering Physics. This variable did not differentiate between the time that students spent actively engaged in the course content while logged in, and when they were logged in but were not engaged. Hence, any results regarding the total time spent in Mastering Physics should be viewed with caution.

Analysis methods

Ordinary least squares (OLS) regression 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 the prior specific achievement in physics and prior general ability of the students, since these were confounding factors that could influence student achievement other than the use of Mastering Physics in the course.

In order to examine the ways in which participation in other course components might interact with the use of Mastering Physics and affect course achievement, we included participation in these other course components in our analyses. In other words, we studied the association between use of Mastering Physics and achievement while controlling for participation in other course components within the second physics course. In this study, participation in other course components was measured by the grades given by the instructor for participating in these components.

Results

The main goal of this study is to examine the relationship between use of Mastering Physics in homework assignments and student achievement for the second sequential physics course. Since learning in the course can be due to course components other than completing homework assignments using Mastering Physics, we also examined how participation in lectures and teaching assistant led activities might affect the association between use of Mastering Physics and student achievement. Two measures of student achievement were examined: average exam scores in the second physics course and BEMA post-test scores. The results for these two outcome measures are presented below.

Average exam scores

Table 2 shows the results from the regression analysis that used the Spring 2016 average exam scores as the outcome measure. The table also shows the platform variables and baseline characteristics that were considered in the model. To address the main goal of the study, we want to know if any of the platform variables that measured use of Mastering Physics are significantly associated with achievement on the course exams. In the analysis, students' baseline characteristics, such as prior specific achievement in physics and prior general ability, were included in the model to account for students' prior differences. Since prior specific achievement and prior general ability can be quite similar constructs, variance inflation factor (VIF) was used to determine the severity of their collinearity and whether they both could be included in a regression model. VIF analysis showed that collinearity was not severe and there is a possibility that prior specific achievement and prior general ability were non-overlapping constructs (see Appendix B for further details on the VIF analysis). Lastly, we also accounted for students' participation in other course components that might affect the relationship between use of Mastering Physics and student achievement. The outcome measure, average exam score, was measured in percentage points.

The regression model in Table 2, which includes variables on participation in other course components, shows that baseline characteristics – prior achievement (average exam score in Fall 2015) and prior ability (ALEKS score) – were both positively and significantly related to average exam scores in Spring 2016. Interestingly, after considering both prior achievement and prior ability, being female or white was not significantly related to the Spring 2016 average exam scores.

As for platform variables, both the platform average score and the platform total hints were positively and significantly related to the average exam scores in Spring 2016. That is, increases in either of the platform variables were associated with increases in the average exam scores. However, platform total time spent was found to be negatively and significantly related to average exam scores. As noted previously, 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, this significant finding should be viewed with caution.

Table 2: Regression results with Spring 2016 average exam scores as the outcome measure

	OLS	OLS Including Other Course Components
	Coefficient (Std. Error)	Coefficient (Std. Error)
Platform Variables (Spring 2016)		
Platform Average Score	0.58***	0.41***
	(0.09)	(0.07)
Platform Total Hints	0.04***	0.04***
	(0.01)	(0.01)
Platform Total Time	-0.15†	-0.16†
	(0.08)	(0.07)
Baseline Characteristics		
Average Exam Score (Fall 2015)	0.56***	0.55***
	(0.04)	(0.04)
Female	-0.44	-1.03
	(1.03)	(1.02)
White	-0.59	-1.00
	(0.95)	(0.92)
ALEKS Score (Standardized)	0.98*	1.04*
	(0.47)	(0.45)
Other Course Components (Spring 2016)		
Lecture		0.02
		(0.02)
Teaching Assistant Led Activities		0.35***

		(0.09)
Constant	-9.48	-29.83***
	(5.89)	(7.87)
Number of Students	374	374

Note:

1. †$p < .10$; *$p < .05$; ** $p < .01$; *** $p < .001$
2. To account for outliers, total hints and total time were truncated at the 99th percentile for this analysis.
3. ALEKS scores were imputed for those students who had missing scores on ALEKS following the multiple impute and delete (MID) approach (Allison, 2002; von Hippel, 2007). Variables used to impute the ALEKS scores include SAT Math and grades obtained in prerequisite math or chemistry courses.
4. The inclusion of average exam score and ALEKS score were not found to be collinear as the largest VIF from this regression was 2.35. Further details of the VIF analysis can be found in Appendix B.

Association between other course components and average exam scores

Since the physics course did not constitute only homework assignments using Mastering Physics, we also examined the relationship that other course components might have with the Spring 2016 average exam scores. We found that teaching assistant led activities had a positive and significant relationship with average exam scores, but lectures did not. It should be noted that when these other course components were added to the regression model, the variables that were originally significant in the regression model remained significant, except for platform average score: though still significant, its magnitude was reduced[1]. (See Table 2).

BEMA scores

Table 3 shows the results for the regression analysis with BEMA post-test scores as the outcome measure. The platform variables, baseline characteristics, and variables on participation in other course components that were considered in this model were the same as those in Table 2 except that average exam score in Fall 2015 was not included as prior specific achievement in physics. This was because BEMA is more general than, and different in format from, the course exams. That is, the average exam

[1] The correlation between average platform score and lecture was 0.45 and the correlation between average platform score and teaching assistant led activities was 0.48. These moderate correlations might explain why the magnitude of the coefficient for platform average score was reduced but still significant when lecture and teaching assistant led activities were included in the regression model.

scores in Fall 2015 would not be an appropriate prior achievement measure when BEMA was the outcome measure.

The regression model in Table 3, which included participation in other course components, shows that the baseline characteristics that were significantly related to BEMA scores included being female and the ALEKS score. In contrast to the regression model, when prior specific achievement in physics was included and average exam scores was the outcome (Table 2), and when the model did not include prior specific achievement in physics, being female became negatively and significantly related to achievement.

The platform average score and the platform total hints were significantly associated with BEMA scores but not the platform total time spent. That is, the higher the platform average score or the more hints that were requested, the higher the BEMA post-test scores.

Table 3: Regression results with BEMA post-test scores as the outcome measure

	OLS	OLS Including Other Course Components
	Coefficient (Std. Error)	Coefficient (Std. Error)
Platform Variables (Spring 2016)		
Platform Average Score	0.36**	0.29*
	(0.11)	(0.12)
Platform Total Hints	0.06**	0.06**
	(0.02)	(0.02)
Platform Total Time	0.07	0.05
	(0.13)	(0.14)
Baseline Characteristics		
Female	-4.47*	-4.68*
	(2.08)	(2.06)
White	0.14	0.42
	(1.75)	(1.80)
ALEKS Score (Standardized)	2.56***	2.49***

	(0.73)	(0.72)
Other Course Components (Spring 2016)		
Lecture		0.01
		(0.04)
Teaching Assistant Led Activities		0.44*
		(0.18)
Constant	15.66*	-20.98
	(7.22)	(15.54)
Number of Students	350	350

Note:

1. †$p < .10$; *$p < .05$; ** $p < .01$; *** $p < .001$
2. To account for outliers, total hints and total time were truncated at the 99th percentile for this analysis.
3. ALEKS scores were imputed for those students who had missing scores on ALEKS following the multiple impute and delete (MID) approach (Allison, 2002; von Hippel, 2007). Variables used to impute the ALEKS scores include SAT Math and grades obtained in prerequisite math or chemistry courses.

Association between other course components and BEMA scores

When examining how other course components might play a role in the relationship between Mastering Physics and BEMA post-test scores, we found that participation in teaching assistant led activities (but not lectures) had a positive and significant relation with BEMA post-test scores. As with the results for average exam scores in Table 2, when variables on other course components were included in the regression analysis for BEMA post-test scores, the significant variables' magnitude did not change much relative to their standard errors. The exception was platform average score, whose magnitude was reduced but still significant (see Table 3).

Robustness checks

A potential concern is the increased possibility of Type I error due to the multiple outcome measures. To correct for multiple comparisons, the Benjamini-Hochberg method (Benjamini & Hochberg, 1995) was used. After correcting the p-values for Column 2 in Tables 2 and 3, the significance results are identical to the ones without the multiple comparison adjustment, except the relation between total time and exam scores in Table 2.

Missing data

There were approximately 397 students who were enrolled in both physics courses in Fall 2015 and Spring 2016 (the longitudinal sample). However, the sample sizes used in the regression analyses were at least 350, indicating that about 88% of the students who were in the longitudinal sample were retained for the analysis. These students were missing data on the outcome variable (that is, exam scores and/or BEMA scores: see Appendix A for further details).The small sample of students with missing data did not indicate a major problem for the analyses.

Implications regarding claims on platform Variables and outcomes

Based on the regression results in Tables 2 and 3, the following claims about platform variables and achievement can be made. Note that for ease of interpretation and effective communication with a broad audience, we have multiplied the regression coefficients by multipliers of 10 or 50 to round up to whole numbers. For example, a unit (or 10%[2]) increase in Mastering Physics homework grade is linked to a 0.4 (or 4%) increase in exam scores. Similarly, an additional hint (or 50 additional hints) is associated with a 0.04 (or 2 percentage points) increase in exam scores.

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

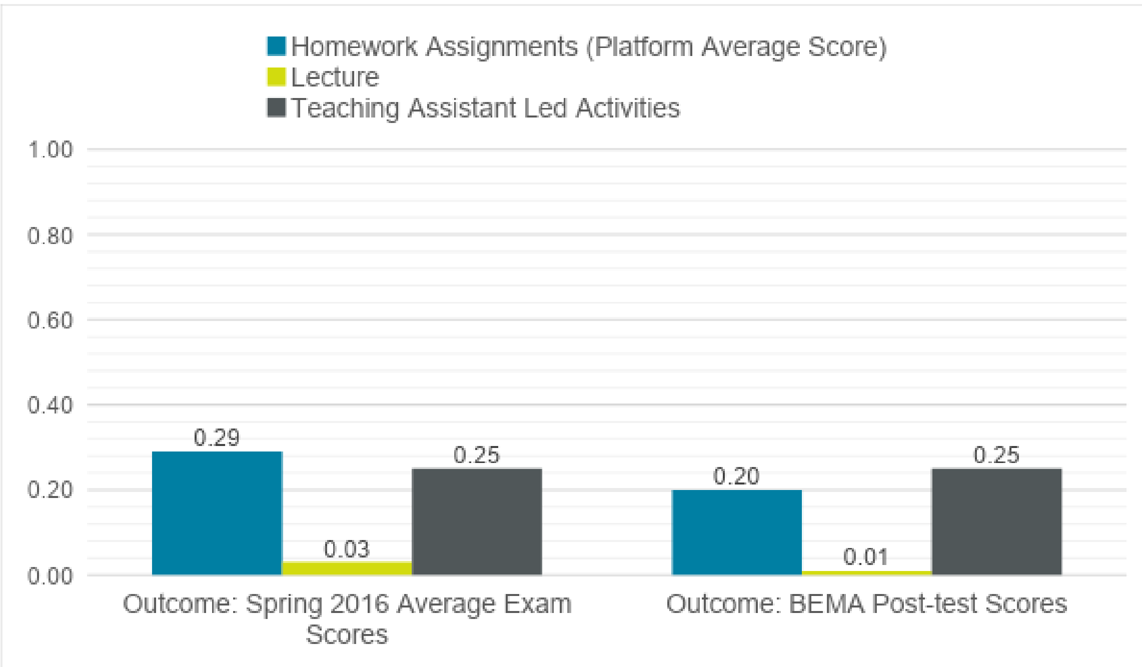
As mentioned previously, homework assignments using Mastering Physics were one of a few course components that might affect students' achievement. To put the above findings in context, we compared the increases in achievement that could have been associated with increases in the scores of each of the course components – homework assignments, lectures, and teaching assistant led activities. In order to do this, we need to examine the standardized coefficients from the regression models, which are the effect sizes. This is to ensure that the unit of comparison is similar across all course components. Figure 7 shows the effect sizes of each of the course components. Appendix C shows the standardized coefficients of all variables included in the regression analyses for both outcome

[2] Mastering Physics homework grades and exam scores are on a percent scale as reflected in the claim statements.

measures – average exam scores and BEMA scores.

When the outcome measure was the Spring 2016 average exam scores, the effect size for platform average score is the largest relative to effect sizes for teaching assistant led activities and lecture. For BEMA post-test scores, the effect size for the platform average score is smaller relative to the effect size for teaching assistant led activities.

Figure 7: Effect sizes (standardized coefficients) for the various course components in the second physics course



Note: All effect sizes are significantly different from zero (p < .05) except for lecture for both outcome measures[3].

[3] Note that in a similar study examining Mastering Physics usage in the first physics course, the effect sizes for homework assignments were also found to be significant while for other course components, the effect sizes were either smaller than the homework assignment effect sizes or was non-significant. See Appendix D for more details.

Discussion

This study is about students who were enrolled in two sequential introductory physics courses in Fall 2015 and Spring 2016, with a focus on their performance in the second physics course while accounting for their achievement in the first physics course. The main goal of the study is to determine if there are any relationships between students' use of Mastering Physics and their achievement on course exams and BEMA during the second physics course. In this study, we wanted to support the validity of any claims we can make about the relationship of Mastering Physics on student achievement by accounting for and statistically controlling for critical confounding variables that could influence students' achievement in the course other than use of Mastering Physics. In other words, we wanted to make valid claims about the strength of the association between use of Mastering Physics and student achievement net of confounding variables such as prior specific achievement in physics and prior general ability, by statistically controlling for these confounding variables in our analysis.

We hypothesized that higher levels of Mastering Physics use, such as higher number of hints requested by students in Mastering Physics, would be linked to higher achievement on the course exams and BEMA. Higher levels of Mastering Physics use would serve to provide students with greater exposure to, and deeper engagement with. Mastering Physics. For instance greater use of hints would expose students to more in-depth thinking about the problem solution. And as detailed in the introduction to this report, the design of Mastering Physics incorporates several principles from learning science in order to enhance learning. Therefore, greater exposure to and deeper engagement with Mastering Physics would be associated with student learning.

The results provided support for our hypotheses. We found that both the platform average score and the platform total hints were positively and significantly associated with average exam scores and BEMA scores, and this association existed even after controlling for both prior specific achievement in physics and prior general ability.

Limitations

This study has a number of limitations. First, the research design allows us to make only correlational claims and not causal claims about Mastering Physics and achievement. We therefore cannot know 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. In light of the fact that we could not account for all possible confounding factors, we are not able to rule out the influence of all the confounding factors on students' achievement in the course. Additionally, the control variables used in the models could be strengthened. Among others, the models would benefit from a better measure of prior adjustment and socioeconomic status as well as additional demographic controls. Another potential limitation is the reliability and validity of the FCI as the instructors introduced some modifications to the original assessment. Lastly, the study made use of data from two sequential physics courses at one school, and solely on students who were not first generation college status. Hence, the extent of generalizability of the findings from this study, particularly to first generation college status students, might be another limitation.

Implications of findings for product implementation and further research

The findings from this study are only a start in understanding how the use of Mastering Physics is associated with student achievement. One direction for future research suggested by the findings of this study is to examine whether there can be other types of interactions that can affect student achievement. In the analyses, we examined only the number of hints and time spent in Mastering Physics, in addition to the average score that the student obtained across all the homework assignments given by the instructor in the second physics course. As mentioned, we were not able to differentiate between the time when students were actively engaged while logged in Mastering Physics, and the time when they were logged in but not engaged. Other types of interactions in Mastering Physics could be a more accurate measure of students' level of engagement in the tool, such as number of solution checks requested by students while completing homework assignments. Such data were, unfortunately, not available in our current study.

Further studies on Mastering Physics could also make use of more robust research methods. For example, they could use a more rigorous experimental or quasi-experimental research design where students are randomly assigned to a treatment or control group to allow for a causal examination of the relationships among variables – to assess whether a change in one platform variable causes a change in an achievement outcome measure. They could also focus on a larger sample across many schools and instructors so that the results would increase generalizability. In this current study sample, there were no first generation college students enrolled in the physics courses, hence the findings were not generalizable to these students. Finally, as suggested above, they could control for a wider and more robust array of student variables (such as students' obligations outside of class and their intended major) to more thoroughly adjust for confounding factors that might influence students' achievement in a physics course.

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Appendix A. Data merge process and resulting analytic sample

Merging and cleaning data was conducted with the intention of using multiple imputation techniques for variables with a high percentage of missing data. Imputation was conducted for the ALEKS score that was used to account for prior achievement during the analysis.

Imputation steps follow suggestions by Allison (2002) and von Hippel (2007) as well as those from a missing data workshop taught by Paul Allison via Statistical Horizons in 2012.

Table A1: Data merge process and resulting analytic sample

Data File	Initial *N*	Data Cleaning Step	*N* Lost or Added	Cleaned *N*
1. *Initial Cleaning*				
Platform Data	1948	No Issues	0	1948
Gradebook Data	1940	No Issues	0	1940
Transcript	1539	No Issues	0	1539
CLASS Data	1858	No Issues	0	1858
2. *Initial Merging*				
Start with Platform Data *(as base dataset)*	1948	No Issues	0	1948
Merge Gradebook Data to Platform Data *(merged dataset now called Master Dataset)*	1948	• 1883 Matched Cases • 122 Unmatched Cases ○ 65 from Platform ○ 57 from Gradebook	57 (Added)	2005
Merge CLASS Data to Master Data	2005	• 1854 Matched Cases • 155 Unmatched Cases ○ 151 from Master ○ 4 from CLASS	4 (Added)	2009

Merge Transcript data to Master Data	2009	• 1972 Matched Cases • 53 Unmatched Cases ○ 37 from Master ○ 16 from Transcript More matches than Initial N because dataset includes students who took two different physics classes (with the same identifier) as two separate observations	16 (Added)	2025
3. Further Cleaning				
Drop cases where students are missing Course identifiers	2025	Drop cases where students don't have a course identifier	16	2009
Drop cases for students who attend class exclusively meant for physics major students	2009	Certain students were in a class for majors only, this small sample was dropped as the class format was very different from the larger class for non-physics. Analyses was focused on the non-physics majors	108	1901
Drop cases where students only take the introductory physics course in Fall 2015 or only the physics	1901	Drop cases of students in classes outside of research question (introductory physics class and	621	1280

course in Fall 2016		did not procced to the second physics class)		
Drop cases where students only take introductory course or only take second physics course [Keep cases where students are in both courses]	1280	• 621 in Intro. Course • 659 in Second Course • 794 Cases in both courses (397 students) • 486 in only one course (243 students)	486	794
4. Secondary Cleaning for Longitudinal Analysis				
Reshape data to convert from long data format to wide data format	794	Instead of two observations per student at two different time points, data was reshaped so there is one observation per student	0	397
Drop cases with missing outcome variable	397	Cases where student is missing data on outcome variable are deleted before running the analysis	23 (Exam Grades); 47 (BEMA)	374 (Exam Grades); 350 (BEMA scores)

Appendix B. VIF analysis for prior achievement (Fall 2015 exam score) and prior ability (ALEKS score)

A potential threat to the validity of the analysis is multicollinearity, which occurs when there are high correlations among independent variables. This leads to unreliable and unstable estimation of regression coefficients.

The most widely-used diagnostic for multicollinearity is the variance inflation factor (VIF). The VIF estimates how much of the variance of a coefficient is “inflated” because of linear dependence with other independent variables. The VIF may be calculated for each independent variable by doing a linear regression of that independent variable on all the other independent variables, and then obtaining the R^2 from that regression. The VIF is calculated using $1/(1- R^2)$. The lower bound of a VIF calculation is 1 but there is no upper bound. Although various authorities have different cutoff points for VIF values that indicate multicollinearity, the general consensus is 10 (Wooldridge, 2012).

During the analysis examining the association between the platform variables and average exam scores, a potential point of concern was the inclusion of both ALEKS scores and Fall 2015 average exam scores. Both variables were intended to be used as a measure of prior achievement and prior ability, but the two measures may exhibit correlations high enough to introduce multicollinearity into the analytic model. When calculating a VIF to assess the potential threat of multicollinearity (and thus bias) to the results, we found the largest VIF value to be 2.35 – a value much lower than the consensus cutoff point. This low VIF estimate suggests that multicollinearity was not a problem in the analytic model. Therefore both ALEKS scores and Fall 2015 average exam scores were included, to reduce bias in our model and to obtain a more accurate estimate of the association between the platform variables and the outcome measure – Spring 2016 average exam scores.

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Appendix C. Regression models with the standardized coefficients

Table C1: Regression models with the standardized coefficients (effect sizes)

	Outcome Measure	
	Average Exam Score	BEMA Post-test
	Effect Size (Std. Error)	Effect Size (Std. Error)
Standardized Platform Variables (Spring 2016)		
Platform Average Score	0.29***	0.20*
	(0.06)	(0.08)
Platform Total Hints	0.11**	0.21**
	(0.04)	(0.07)
Platform Total Time	-0.12†	0.03
	(0.06)	(0.09)
Baseline Characteristics		
Standardized Average Exam Score (Fall 2015)	0.59***	--
	(0.05)	
Female	0.01	-0.29*
	(0.07)	(0.13)
White	-0.09	0.03
	(0.07)	(0.11)
Standardized ALEKS Score	0.08*	0.15***
	(0.03)	(0.04)
Standardized Course Components (Spring 2016)		
Lecture	0.03	0.01

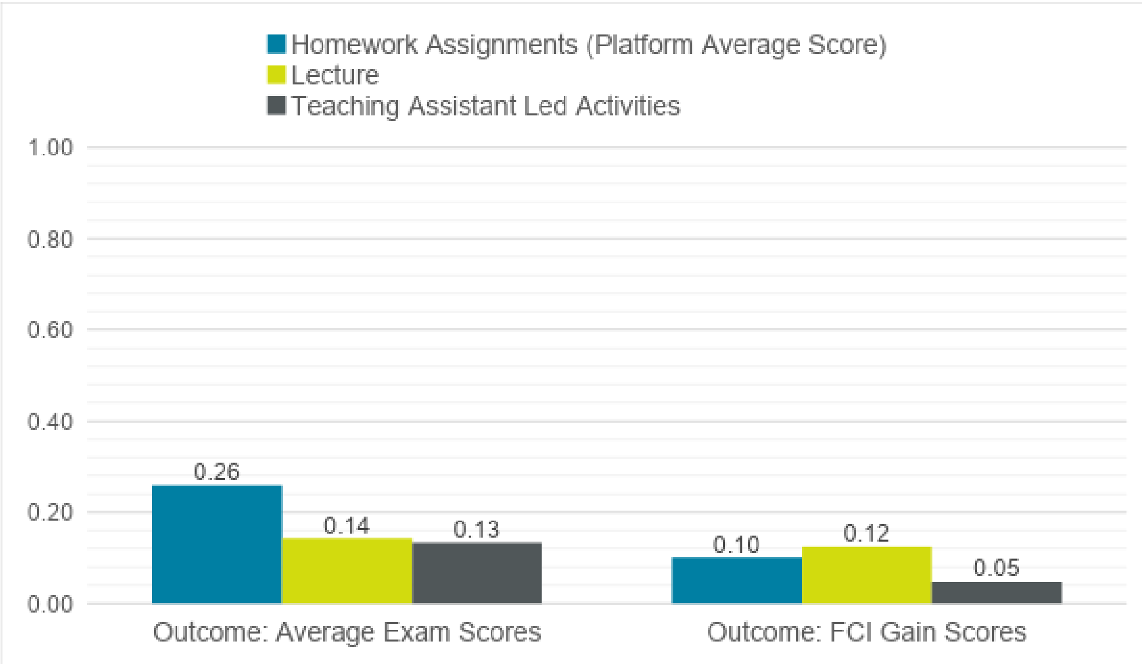
	(0.04)	(0.05)
Teaching Assistant Led Activities	0.25***	0.25*
	(0.06)	(0.10)
Constant	-0.12*	0.01
	(0.06)	(0.10)
Number of Students	374	350

Note:

1. $^{\dagger}p < .10$; $*p < .05$; $** p < .01$; $*** p < .001$
2. To account for outliers, total hints and total time were truncated at the 99th percentile for this analysis.
3. ALEKS scores were imputed for those students who had missing scores on ALEKS following the multiple impute and delete (MID) approach (Allison, 2002; von Hippel, 2007). Variables used to impute the ALEKS scores include SAT Math and grades obtained in prerequisite math or chemistry courses.

Appendix D. Effect sizes for a similar study examining Mastering Physics use in the first physics course

Figure D1: Effect sizes (standardized coefficients) for the various course components in the first physics course



Note: All effect sizes are significantly different from zero (p < .05) except for teaching assistant led activities when the outcome measure is FCI Gain Scores.

Appendix E. Table 2 and 3 *p*-values adjusted for multiple comparison using Benjamini-Hochberg method (*q*-values)

Table E1: Adjusted *p*-values

	Exam Scores		BEMA Scores	
	Original *p*-value	Adjusted *q*-value	Original *p*-value	Adjusted *q*-value
Platform Variables (Spring 2016)				
Platform Average Score	0.0000	0.0000	0.0154	0.0154
Platform Total Hints	0.0087	0.0087	0.0024	0.0047
Platform Total Time	0.0361	0.0723	0.7370	0.7370
Baseline Characteristics				
Average Exam Score (Fall 2015)	0.0000	0.0000		
Female	0.8768	0.8768	0.0235	0.0469
White	0.2219	0.4438	0.8135	0.8135
ALEKS Score (Standardized)	0.0149	0.0149	0.0006	0.0012
Other Course Components (Spring 2016)				
Lecture	0.3132	0.6264	0.7945	0.7945
Teaching Assistant Led Activities	0.0000	0.0000	0.0122	0.0122
Constant	0.0000	0.0000	0.1779	0.1779

Appendix F. Course syllabus

General Physics: Electricity and Magnetism (Calculus Based)

PHYS 212R & 212L: Electricity and Magnetism

Course Credits: 4

Notes

The lecturer and your recitation TAs are your first point of contact for physics related questions.

Required Text

The text for this course is Physics for Scientists and Engineers: A Strategic Approach by Knight, 3rd edition. This course will cover Chapters 25–35. (This book is the 2nd Penn State custom edition.) The soft-cover PSU custom “split” with these sections, available at the bookstore, also contains access to the MasteringPhysics homework system we will be using in the course.

In addition you are also required to have an i>clicker. These are available from the bookstore and elsewhere. Using your i>clicker in lecture is part of your grade. You can find out about obtaining and registering i>clickers on the ITS Clicker website. There is a link in the Lessons folder to directly register your clicker. If you do not register your clicker, then you cannot earn a lecture participation grade (3% of the total course grade).

Course Description

Calculus-based introduction to classical electricity and magnetism, including such topics as, electric charge and electric fields, Gauss's law, electric potential, capacitance, current, resistance, and circuits, magnetic fields, and fields due to currents, induction and inductance, magnetism of matter, Maxwell's equations, and electromagnetic oscillations. You must be registered for both PHYS 212L and PHYS 212R to earn a grade in this course.

Course Objectives

Upon completion of PHYS 212, students should be able to demonstrate a mastery of:

1. 1. Electric charges, fields, and forces
2. 2. Electric potential and potential energy
3. 3. Resistance, current and circuits (both DC and AC)
4. 4. Magnetic fields

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5. 5. Electromagnetism and electromagnetic waves For a more detailed list of course objectives, please see the Exams folder.

Tentative Schedule

See the Lessons Tab for the schedule of readings, lecture topics, recitations and laboratories. Exam Dates: MT1, MT2, Final Exam

Course Requirements

You must be registered for BOTH the lecture (212L) and the recitation/laboratory (212R)

Problem Set assignments – In general, there is one homework assignment per week. The due date and time for each assignment appears on MasteringPhysics. We will be using an online computer grading system called MasteringPhysics (http://www.pearsonmylabandmastering.com/northamerica/) to grade the homework. Access to MasteringPhysics is provided in the PSU custom book in the bookstore. This system allows you to submit your homework at any time. Your grade on each assignment will be available immediately and, in most cases, you will have multiple tries to arrive at the correct answer. Any work done after the due date will not receive credit and no extensions will be given. Because problem sets are available at least a week before the due date and can be done in advance, NO excuses are allowed (see bottom of page for more info on excuse policy). Students are encouraged to work together and collaborate on assignments. Work submitted for individual assessment must be the work of the individual student. Please refer to the Academic Integrity Policy below.

Course Prerequisites Prerequisite: PHYS 211, MATH 140

Co-requisite: MATH 141

Grading Policy

Your grade in the course will be based on your participation in lecture, on your performance in the labs, in recitation, on the homework assignments, and on the exams with the following weights:

Lecture Participation	**Problem Sets**	**Recitation**	**Laboratories**	**Midterm 1**	**Midterm 2**	**Final**
3%	9%	9%	9%	20%	20%	30%

The homework score is calculated as the average of the scores of each homework assignment; all assignments are weighted equally. Each assignment's score is calculated as 100 ×(points earned on assignment / total points possible on assignment). The number of points earned on a problem

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decreases on each submission after the first. On multiple choice questions, on each submission after the first, credit will decrease by 100% (number of answer options – 1). On all other questions, on each submission after the first, credit will decrease by 3%.

You are responsible for verifying all of your scores in ANGEL and reporting any concerns (with the exception of the last recitation, lab, and lecture scores and final exam score) before the final meeting of the course. You are responsible for verifying all of your scores and reporting any concerns (with the exception of the final exam score) before the final exam takes place.

Your clicker score each day is calculated as the sum of your score for the quiz question(s) at the start of class (based on your answer) and your score for the participation questions throughout the rest of the class (based on your participation). The quiz is worth 50 point each day, and the participation questions are worth 50 point each day. Your clicker score for the class is calculated by how many of the clicker points you earn in each of several periods (Weeks 1 & 2, Weeks 3 & 4, Weeks 5 & 6, and Weeks 7 - 9). In the Grades tab, you can find how many points must be earned for a full score in any period (there are more points available than are necessary for a full score).

Final letter grades for the course will be based on an absolute scale. The course score will be rounded to the nearest integer. No curving of any kind will be employed unless the combined average exam score (computed as the combined average of all students' scores on all midterm and final exams taken to date) is less than 70%. In such cases, the grades on the most recent exam will be adjusted by additively raising the exam scores to allow the combined exam average to meet the target minimum of 70%.

The break points for the various grade levels are:

Lowest Percentage	**Letter Grade**	**Highest Percentage**
93%<	A	<100%
90%<	A-	<93%
87%<	B+	<90%
83%<	B	<87%

80%<	B-	<83%
77%<	C+	<80%
70%<	C	<77%
60%<	D	<70%
0%<	F	<60%

Grades will be rounded to the nearest integer at the end of the course.

Attendance Policy

Lecture

You must attend the lecture section for which you are registered ("clicker" participation in a lecture not registered for will not be counted for a grade.) We will use i>clickers in class for three different types of questions in lecture:

(1) reading quizzes or review questions at the beginning of each class (graded for correctness),

(2) in-class concept questions designed to challenge your thinking (graded for effort), and

(3) review of material covered to make sure everyone understands what we just discussed (graded for effort).

You can find out about obtaining and registering i>clickers on the ITS Clicker website. When registering you must use your PSU email address (e.g., abc123@psu.edu) to register your clicker in order to receive credit. If you register through the link in Angel (in the Lectures folder) it will automatically register you correctly.

“Clicker questions” are generally multiple choice conceptual questions that are designed to help identify common misconceptions and provide feedback during the class. They are designed to help you know when you understand the topic at hand, and your instructor to know when more discussion is needed and when to move on to the next topic.

Each lecture you will earn points based on your answers to the beginning-of-class reading or review questions, the concept questions, and the review questions. The number of opportunities to earn points in this way is greater than the maximum number of points you can earn. For this reason, there will be no adjustments for forgetting to bring your clicker to lecture, and no extra-credit or make-up work for absences. If you fail to register your clicker in a timely manner, you will not get credit for lectures that occurred before you registered your clicker. If you get a new clicker during the semester, be sure to register it right away. To avoid accidentally swapping a clicker with another student, be sure to put your name or some other identifying feature on your clicker. You must attend your scheduled 212L section (participating in another lecture section will not contribute to your lecture participation grade).

Appropriate use of clickers by their owner during their class is an expectation of the course. Asking someone to use your clicker for you is asking that person to help you cheat. If someone asks you to use their clicker, that person is asking you to help them cheat. If you agree, you have helped them cheat. If you observe someone is cheating - e.g., you see someone using two clickers - you are obligated to report it. If you do not, you are helping them to cheat. Please refer to the Academic Integrity Policy of this syllabus for more details.

Laboratories

Laboratory sections meet once a week in room 313 Osmond. Your meeting time is determined by your 212R section number. You must attend the laboratory section in which you are scheduled — no switching is permitted.

The laboratories are designed to provide you with hands-on experience with the material being investigated in class. Laboratory instructors lead the laboratory sessions and act as your guides as you explore the material. You will work collaboratively in three-member lab groups to carry out the experiments. The experiments are in the Laboratories folder.

During the lab session, your group will prepare a single write-up, addressing specific points of the experiments. This write-up must be submitted by your group before the end of the laboratory session and all group members must be present when the report is submitted in person to the laboratory instructor.

Recitation

Recitation sections meet once a week. Your meeting time and room are determined by your 212R section number. You must attend the section for which you are registered. No switching is permitted.

In these sections you will work collaboratively in three-member groups to complete problem-solving exercises. These problem solving activities are an invaluable component of learning physics, and will provide you with much more opportunity to explore problem solving techniques than you will have in class.

The recitation activities are available in the Recitations folder in ANGEL. While only one paper is turned in, every student needs to bring an individual copy of the pertinent activity to the recitation section.

All students should plan to take their exams at the scheduled times. Students can request makeup exams only by submitting a valid written (or e-mailed) excuse to the course instructor. In the case of sudden or unexpected events that will cause them to miss an exam, students are required to notify the course instructor prior to the exam or as soon as is reasonably possible.

Exam Policy

There will be two midterm exams (W 2/18 and W 4/1) and a cumulative final exam (date to be set by the Registrar in 4/4 - 4/8). Exams will be closed book. Relevant physical constants and formulae will be provided. Cellular phones, smart phones, any other communication devices, tablet computers, and organizers, and additional paper are not allowed. Room is provided for scratch work in the exam booklet. The exams will be based on the assigned reading in the textbook, the material covered in lecture, the recitations, the laboratories, and the homework assignments. Please see the Course Content Objectives and the Exams folder in Angel for more information about the content assessed on the exams in this course.

Academic Integrity

As described in The Penn State Principles, academic integrity is the basic guiding principle for all academic activity at Penn State University, allowing the pursuit of scholarly activity in an open, honest, and responsible manner. We expect that each student will practice integrity in regard to all academic assignments and will not tolerate or engage in acts of falsification, misrepresentation, or deception. To protect the fundamental ethical principles of the University community and the worth of work completed by others, we will record and report to the office of Judicial Affairs all instances of academic dishonesty.

The University and Departmental policy regarding academic integrity can be found on the course web page with links to the faculty senate policy: http://www.psu.edu/ufs/policies/47-00.html#49-20.

Disability Policy

Penn State welcomes students with disabilities into the University's educational programs. If you have a disability-related need for reasonable academic adjustments in this course, contact the Office for Disability Services (ODS) at 814-863-1807 (V/TTY). For further information regarding ODS, please visit the Office for Disability Services Web site at http://equity.psu.edu/ods/.

In order to receive consideration for course accommodations, you must contact ODS and provide documentation (see the documentation guidelines at http://equity.psu.edu/ods/guidelines/documentation-guidelines). If the documentation supports the need for academic adjustments, ODS will provide a letter identifying appropriate academic adjustments. Please share this letter and discuss the adjustments with your instructor as early in the course as possible. You must contact ODS and request academic adjustment letters at the beginning of each semester.

Miscellaneous

Excuse and Makeup policy Laboratory and Recitation

The laboratory and recitation components of this course are structured around collaborative learning. You must be present in laboratory or recitation to do these assignments. If you are absent from a laboratory or recitation section with a valid excuse, as described under "Valid Excuse Policy", fill out the excuse form in Angel (in the Laboratories or Recitations folder) within one week of the absence. You will NOT be required to make up the missed activity. Your score for the missed activity will be recorded as a zero until an excuse form is filled and recorded. If you are absent without a valid excuse, a score of zero will be recorded for that assignment. If a student is more than ten minutes late to a lab, they cannot receive any credit for that period's so be on time!

Homework

You must complete the homework assignments as scheduled. The assignments are available early so no excuses are accepted. Even technical glitches are not valid excuses. Examinations All students should plan to take their exams at the scheduled times. Students can request conflict exams only by filling the conflict exam signup form in the Exams folder. In the case of sudden or unexpected events that will cause them to miss an exam, students are required to notify the course administrator prior to the exam or as soon as is reasonably possible. Valid Excuse Policy Up to three (3) valid excuses will be accepted for a student throughout the entire course. More than three absences will interfere excessively with student learning. In extreme circumstances in which a student requires four or more absences to be excused, he or she must contact the course administrator directly to discuss the situation as soon as possible. Requests to be excused from a missed evaluative event due to reasons that are based on false claims is cheating and will be treated as described in the Academic Integrity Policy 49-20 http://science.psu.edu/current-students/Integrity/Policy.html. * The student must provide all requested information on the Excuse Form and electronically sign the form. Incorrect or missing information will result in the request for an excused absence to be denied. * Family emergencies include a death in the immediate family, death of a close friend, sudden hospitalization of a close family member, and events of similar gravity. Students should inform their appropriate teaching assistants about the family emergency as soon as possible. * To obtain an excuse for university-approved curricular and extra-curricular activities, a student needs to obtain a letter (or a class absence form) from the unit or department sponsoring the activity. The letter must indicate the anticipated absence dates, and it must be submitted to the excuse submission dropbox along with the first excuse request before the first absence. * In the case of religious holidays, students should submit the excuse request before the date of the absence. Since University regulations require course instructors to make conflict exams available to students, missing a laboratory or recitation due to an examination in another course is not considered a valid excuse. You have one week from the absence to submit an excuse; otherwise it will be denied, barring extenuating circumstance (e.g., no access to the Internet due to reason for absence, such as an extended hospitalization).