Pearson

Technical Report

Mastering Physics A study of two semesters of an introductory, prerequisite physics course at Penn State University

Authors
Christine Leow
Kenenth Lee
Yun Jin Rho
(in collaboration with the instructors at Penn State University)

Pearson Global Product Organization
Efficacy & Research
Impact Evaluation

Table of Contents

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 4, 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 MasteringPhysics in an introductory, prerequisite physics course and students' learning in the course.

Intended Outcomes and Study Sample

In order to determine if students are learning in their 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 course. Another is derived from the Force Concept Inventory (FCI), a widely accepted standardized test that measures a student's mastery of concepts commonly taught during the first semester of physics. The FCI was given to the students at the beginning and at the end of the semester.

The students in the study were enrolled in a physics course at Penn State University for Fall 2015 and Fall 2016. This physics course on calculus-based introduction to classical mechanics is an important prerequisite course for later coursework in science and engineering disciplines. Students who were not physics majors were enrolled in this course. Two instructors taught the three classes in the course in Fall 2015 while one instructor taught all three classes in Fall 2016. Almost 900 students were enrolled in each semester, though only 600 students participated in the study. All instructors used Mastering Physics for homework assignments.

Research Questions

The primary goal of this study was to assess the relationship between use of Mastering Physics (as determined by time spent, hints used, and average score on the homework assignments in Mastering Physics) and student learning (as measured by achievement on the course's exams and the FCI). 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 FCI scores) in the course than others? What is the contribution that the following factors make to students achieving a higher grade in the course?
    a. first generation college status
    b. gender
    c. prior achievement,as measured by Assessment and Learning in Knowledge Spaces (ALEKS)
    d. Mastering Physics usage patterns (such as 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 and achievement while taking into account participation in other course components?

Key Findings

Based on the hierarchical linear modeling (HLM) results, we found that first generation college status was not significantly related to higher achievement, but being female was negatively associated with both average exam scores and FCI gains. Prior achievement was positively and significantly associated with average exam scores but not FCI gains.

The following claims about platform variables and achievement can be made:

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 2% increase in FCI gains.

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

Mastering Physics Platform Variables	Achievement Outcome Measure	
	Average Exam Score	**FCI Gain**
Average Score on Homework Assignments	Effect Size = 0.26	Effect Size = 0.10

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

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.

Other course components were also examined, to determine if they had a significant association with the outcomes measures examined in this study. We found that both the lecture and teaching assistant led activities were positively and significantly associated with average exam scores. For the outcome measure focused on FCI gain scores, we found that participation in lectures (but not teaching assistant led activities) had a positive and significant association with FCI gains.

To put these claims and 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 compared the standardized coefficients in the HLM models, which are essentially the effect sizes.

When the average exam score was used as the outcome measure, the effect size for platform average score was found to be 0.26, twice as large as that for lecture and teaching assistant led activities. In other words, an increase in achievement on the homework assignments is associated with twice an increase in average exam scores compared to other course components. For FCI gains as the outcome measure, the effect size for platform average score was found to be 0.1, which is about the same as the effect size for lectures, indicating that increases in the scores for homework assignments and lectures are associated with the same increases in FCI gains.

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 achievement in their course exams and FCI. 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 two crucial variables that have been found to be strongly related to achievement – prior achievement, as measured by ALEKS, and socio-economic status, as measured by first generation college status (What Works Clearinghouse, 2016). This speaks to the validity of the relational claims we are making in this study.

Additionally, the study made use of data from only one course for two semesters, taught by two instructors, at a single school. Hence, 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 this study, 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 instructors in the course. As mentioned, we were not able to differentiate between the time when students were actively engaged while logged in to 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. 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 adjust more thoroughly for confounding factors that might influence students' achievement in a physics course other than use of Mastering Physics.

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 4, 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 in the study 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).

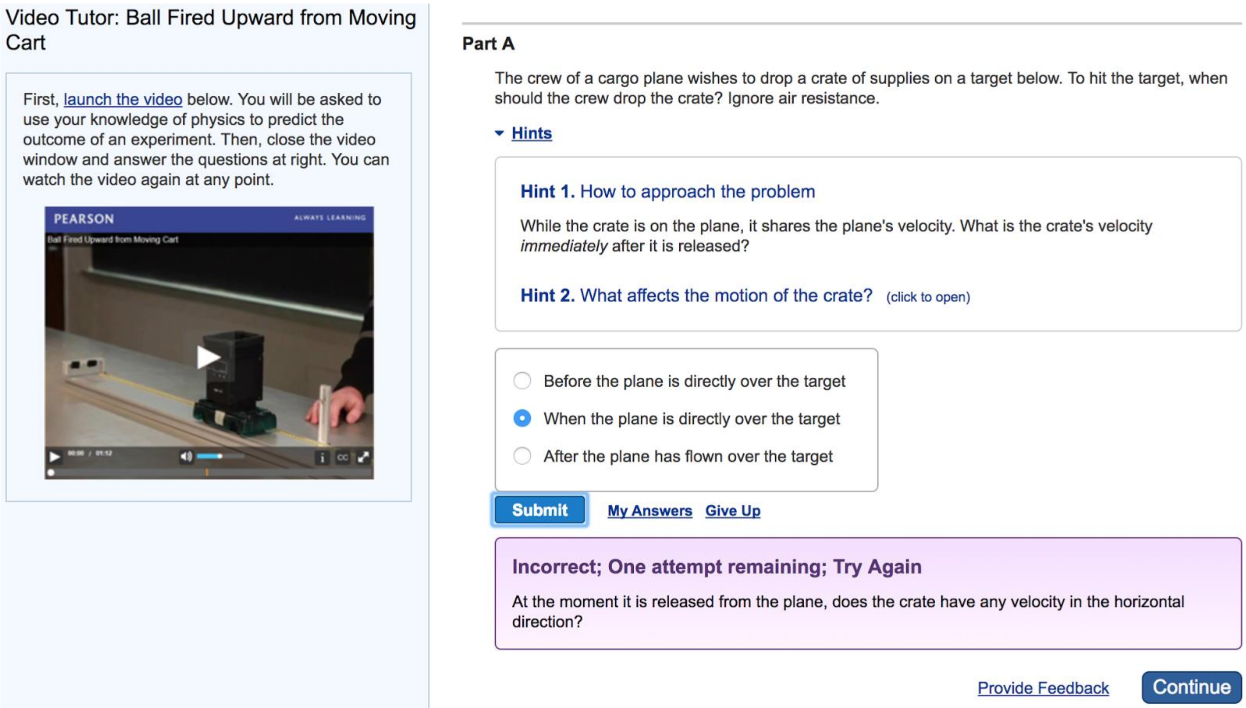
Scaffolding

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 the correctness of 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. One of two optional hints is revealed above the problem; a student can choose whether to view either hint. 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. In this study, 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 Force Concept Inventory (FCI). The latter is a widely accepted standardized test that measures a student's mastery of concepts commonly taught during the first semester of physics. For the FCI used at Penn State, the test was modified where 70% of the questions (i.e. 21 questions) came from the original FCI test and the rest (i.e. 9 questions) were new. Besides focusing on this goal, the study also explored whether student participation in other instructional components of the 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 FCI scores) in the course than others? What is the contribution that the following factors make to students achieving a higher grade in the course?
    a. first generation college status
    b. gender

c. prior achievement, as measured by Assessment in Learning and Knowledge Spaces (ALEKS)
d. Mastering Physics usage patterns (such as 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 and achievement while taking into account participation in other course components?

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 as many extraneous factors as possible that might affect student achievement, 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.

Two important confounding factors that we were able to control for in the analysis were students' prior achievement, as measured by ALEKS, and students' socio-economic status, as measured by first generation status (What Works Clearinghouse, 2016). Being able to control for these two important confounders enables us to strengthen the claims we can make about the use of Mastering Physics. This design is similar to the case-control design that is frequently used in health studies, where one statistically controls for additional factors that might influence the outcome.

Our main hypothesis is that higher usage of Mastering Physics, as reflected in students' greater level of engagement with the tool, will be linked to higher achievement on course exams and FCI. The logic behind our hypotheses 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 FCI.

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 FCI.

Method

This study examined the association between the use of Mastering Physics and students' achievement on the course exams and FCI, after controlling for confounding student characteristics that might affect achievement. Confounding student characteristics that were controlled for in the study included prior achievement and socioeconomic status.

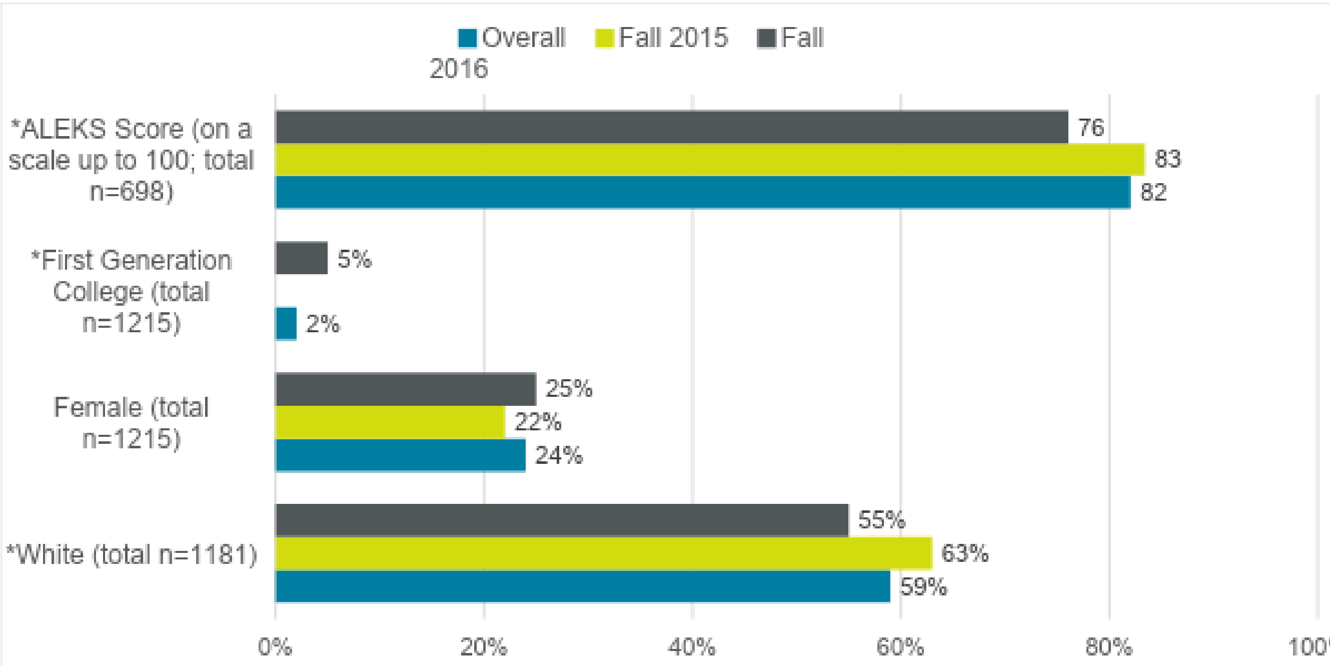
Mastering Physics was used by the instructors in this study for homework assignments. We measured students' Mastering Physics usage by the number of hints made, the time spent, and the performance in homework assignments within Mastering Physics. In addition, since students' achievement in the course might be affected by course variables other than engagement in Mastering Physics, we also examined course components such as students' participation in lectures and teaching assistant led activities, and how these might interact with 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 Fall 2016 semesters. The course examined was an introductory physics course for non-physics majors, an important prerequisite for later coursework in science and engineering disciplines. It is a course on calculus-based introduction to classical mechanics. Though different instructors taught the course for the two semesters, the course format was similar[1]. About 900 students were enrolled in each semester, with approximately 600 students in each semester who consented to the study. Of the approximate 600 students who consented to the study, there are some differences in their characteristics between the two semesters, which would be taken into account in the analysis. Overall, slightly more than half of the students were white, with only about a quarter of the students enrolled being female, and only a handful of them were first generation college students. Figure 2 below shows the characteristics of the students enrolled in the course.

[1] Two different instructors taught in Fall 2015, one of them teaching two of the three lectures. Fall 2016 had only one instructor, who was also the principal investigator in the data collection for this study.

Figure 2: Characteristics of students who were enrolled in the introductory physics course



*Note: *Fall 2015 and Fall 2016 were significantly different at p<.01*

Data

This study took place as part of a collaboration between the instructors of the course and Pearson. The instructors had collected various data on student characteristics, course grades, and FCI scores for a prior study. Pearson then shared the platform data on Mastering Physics with the instructors. Another physics faculty at Penn State, not involved in the study, 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. In addition, we have used students' first generation college status as a proxy for socio-economic status, which is an important student characteristic that we need to control for in the analysis.

Prior achievement

ALEKS and SAT Math scores were also available. Either of these scores is a good measure of students' prior achievement, which is another important characteristic that we need to control for in the analysis. Unfortunately, students have data on either ALEKS or SAT Math, so if we use either, we will lose a large number of students due to missing data. The amount of missing data for ALEKS was 41% while that for SAT Math was 58%. In order to address the problem of missing data, we conducted imputation for the ALEKS scores, which was chosen because more students had ALEKS scores than SAT scores and hence they do not have to rely on imputation. SAT Math scores and grades in prerequisite math and chemistry courses were used to impute missing ALEKS scores. The procedure used for imputing missing ALEKS scores is presented in Appendix B.

Course grades and FCI

In both semesters, there were three interim exams and one final exam. The average exam score was calculated based on the four course exams and used as one of the outcome measures. Students also took the FCI at the beginning of the course (FCI pre-test) and at the end of the course (FCI post-test). The FCI was another outcome measure examined in this study. Specifically, the FCI gain score as an outcome measure was examined. The FCI gain score was calculated as illustrated below. The formula used is the normalized gain score, which is the ratio of gain to the maximum possible gain or the ratio of loss to the maximum possible loss (Marx & Cummings, 2007). Essentially, this formula allowed us to account for students with high FCI pre-test scores who are unable to achieve the same magnitude of potential score improvements relative to students with low FCI pre-test scores.

If FCI post-test score is greater than FCI pre-test,

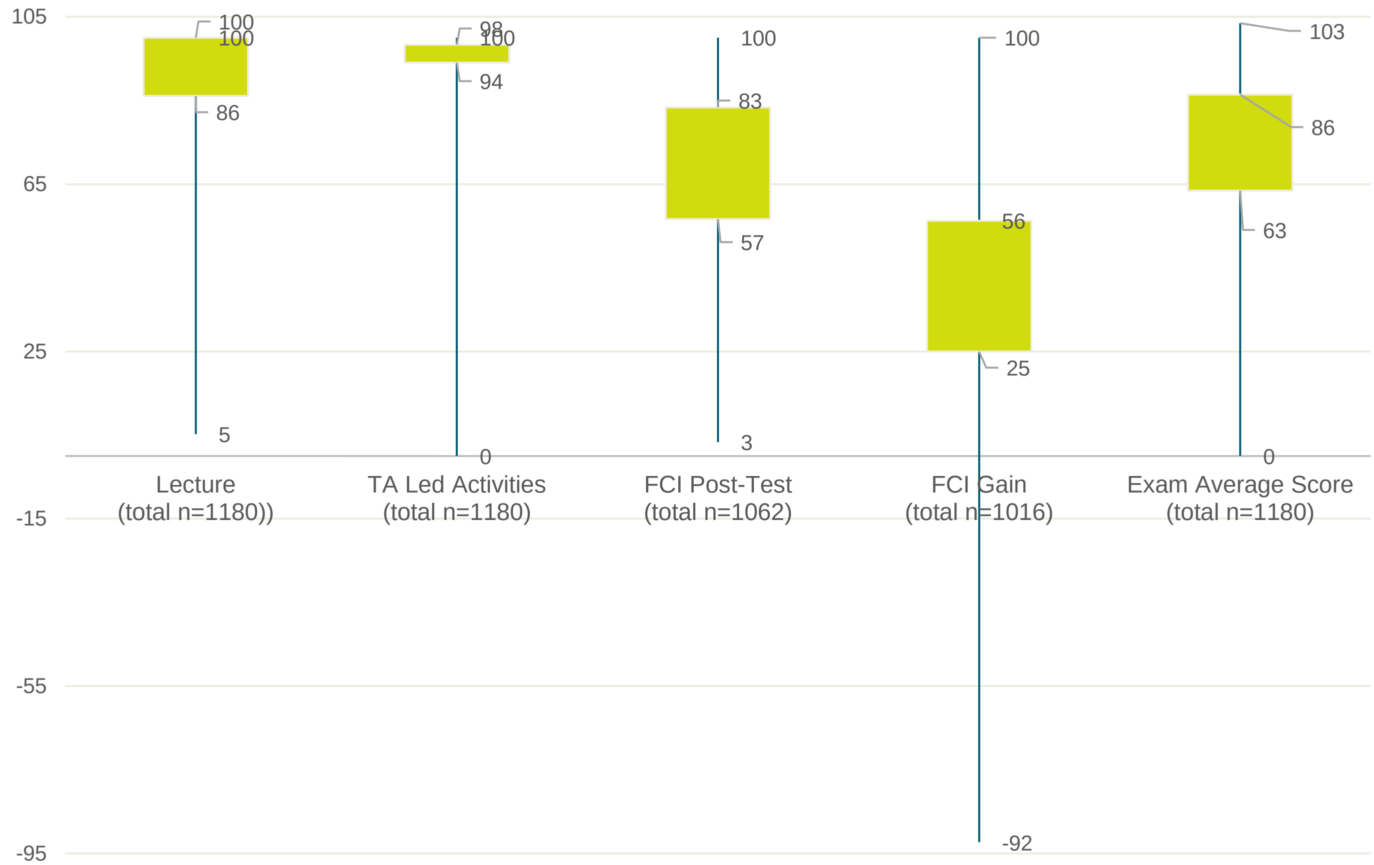
then FCI gain = $\frac{FCI\ post - FCI\ pre}{(100 - FCI\ pre)}$

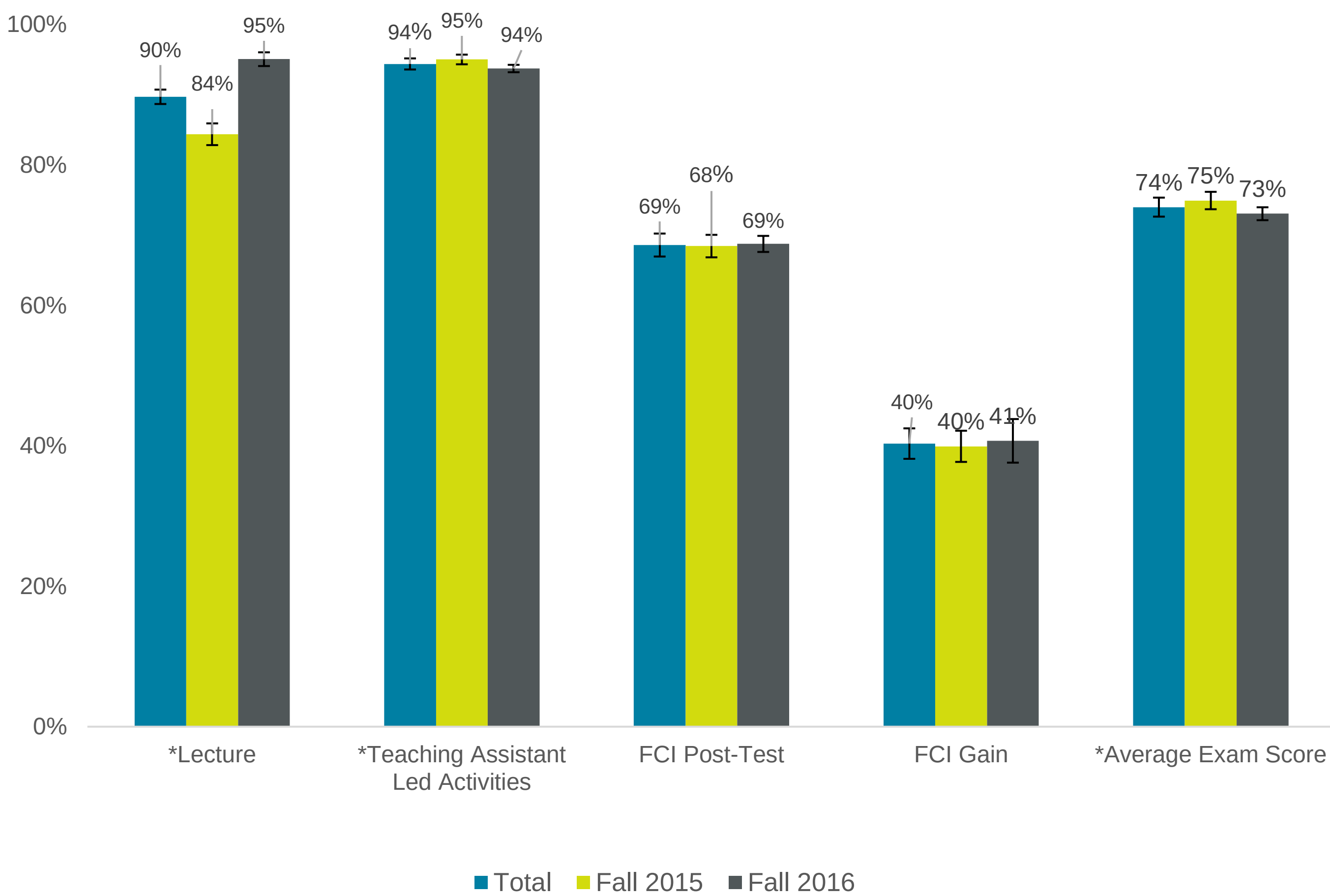
If FCI post-test is less than FCI pre-test,

then FCI gain = $\frac{FCI\ post - FCI\ pre}{FCI\ pre}$

Besides exam scores and FCI scores, students also received scores for various components of the 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, in-class concept questions, and 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 3 below shows the scores that the students received for the various course components as well as their FCI scores.

***Figure 3*: Scores for the various course components and FCI scores**



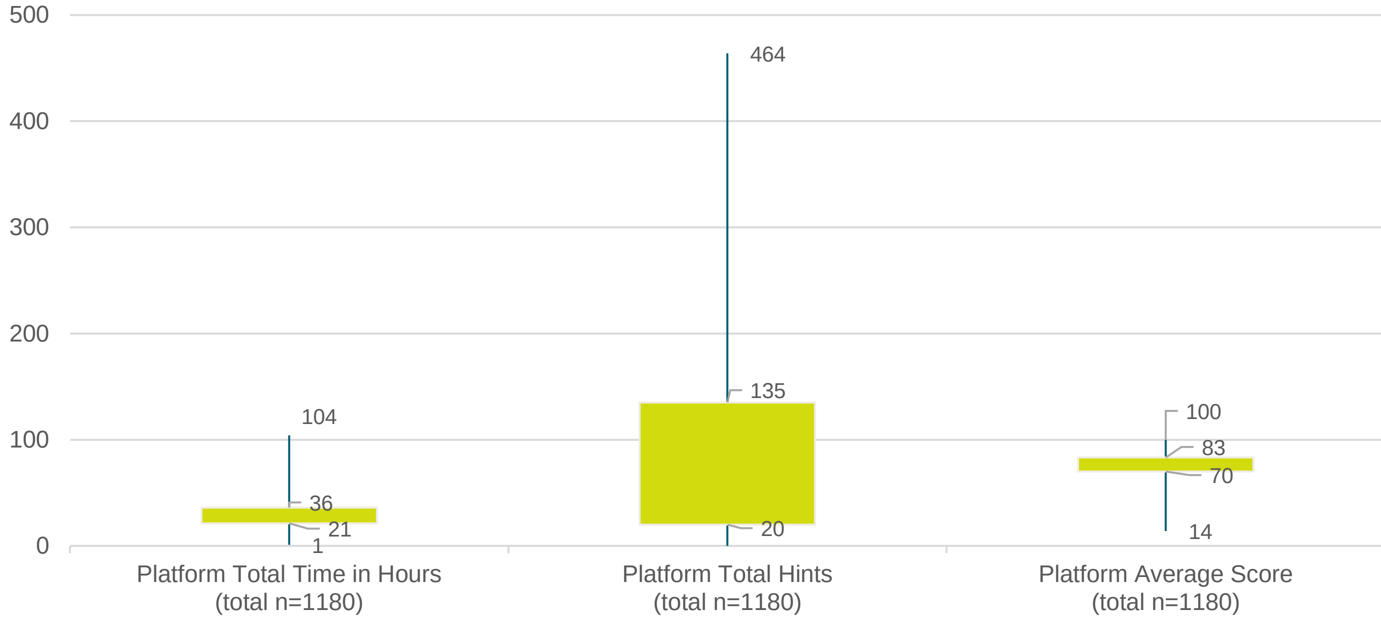


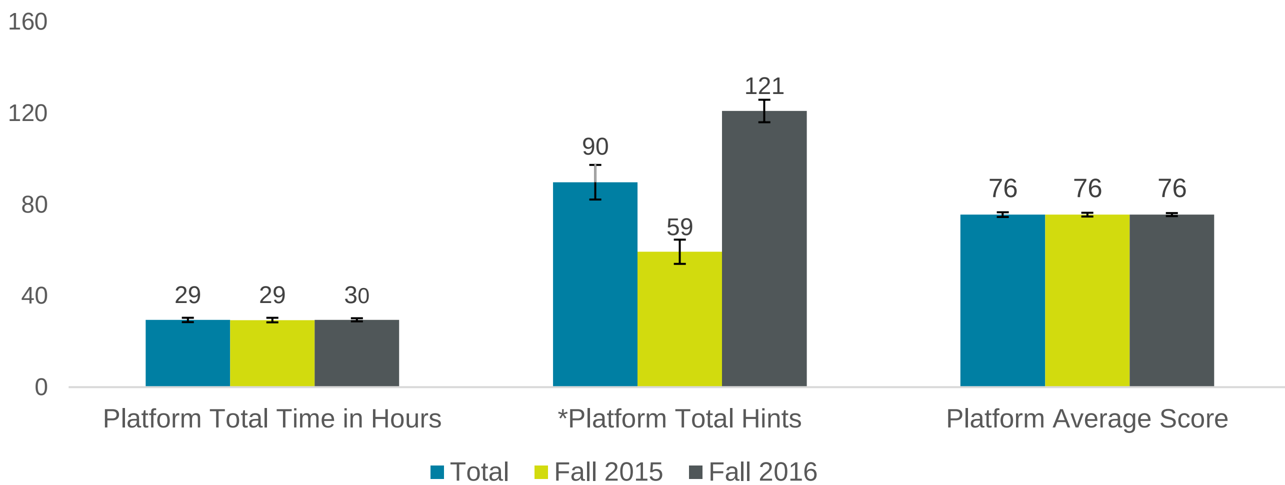
*Note: *Fall 2015 and Fall 2016 were significantly different at p<.05*

Mastering Physics platform data

The instructors used Mastering Physics to assign homework for the course. 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 4 shows Mastering Physics usage and the average score for homework assignments. These are similar in both semesters, except for the total number of hints. The mean for the total hints requested by students in Fall 2016 was almost double that of Fall 2015. However, there was no penalty or bonus for hints in either semester. The students could always view them when needed.

Figure 4: Mastering Physics use based on platform data





*Note: *The difference in platform total hints between fall 2015 and fall 2016 was significant at p<.001.*

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, for both semesters, 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. The threshold for the amount of homework assignments completed was lower for Fall 2015 than Fall 2016 (75% versus 95%). 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.

Platform total 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

Hierarchical Linear Modeling (HLM) was conducted to assess the relationship between Mastering Physics use and student achievement on the course exams and FCI. 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 with students in another semester. Most conventional statistical methods assume the independence of the analysis units, which is not the case in our study. It should also be noted that different instructors taught the two semesters. Hence, in the analysis, we will not be able to separate the effects of the different classes in the different semesters from the different instructors.

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 HLM analyses. In other words, we studied the association between use of Mastering Physics and achievement, while controlling for participation in other course components. In this study, participation in other course components were measured by the grades given by the instructors for participating in these various course components.

Results

The main goal of this study is to examine the relationship between use of Mastering Physics in homework assignments and student achievement. Since learning in the course can be due to course components other than completing homework assignments using Mastering Physics, we also examined the ways that 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 course and FCI scores. The results for these two outcome measures are presented below.

Average Exam Scores

Table 1 shows the results from the HLM analysis that used average exam scores as the outcome measure. The table also shows the platform variables and baseline covariates 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, is significantly related to achievement on the course exams. In the analysis, students' baseline characteristics were included in the model so that they would account for students' prior differences. In addition, we accounted for students' participation in other course components that might affect the relationship between use of Mastering Physics and student achievement. The average exam score was measured in percentage points.

The HLM model in Table 1 shows that the baseline characteristics of being female and ALEKS scores were significantly related to average exam scores. Being female was related to lower average exam scores, while higher ALEKS scores were related to higher average exam scores. Student scores on their performance in lecture and teaching assistant led activities were both positively related to average exam scores.

But to address the main goal of this study, we turn to the findings for the platform variables. Table 1 shows that both the platform average scores and platform total number of hints requested were positively related to higher average exam scores. That is, with an increase in a unit of the platform average score, there is a 0.4 percentage point increase in the average exam score. For an additional hint made, there is an increase in 0.01 percentage point in average exam score.

Table 2: HLM results with the average exam scores as the outcome measure

	HLM		HLM Including Other Course Components	
	Coefficient	Std. Error	Coefficient	Std. Error
Platform Variables				
Platform Average Score	0.544***	(0.047)	0.363***	(0.054)
Platform Total Hints Requested	0.014†	(0.006)	0.014†	(0.007)
Platform Total Time	-0.026	(0.050)	-0.048	(0.050)
Baseline Characteristics				
Female	-8.330***	(0.984)	-8.492***	(0.960)
White	1.445†	(0.866)	0.644	(0.850)
First Generation College Status	-2.396	(2.735)	-3.357	(2.702)
ALEKS Score (Standardized)	3.610***	(0.480)	3.660***	(0.471)
Other Course Components				
Lecture			0.133***	(0.030)
Teaching Assistant Led Activities			0.231***	(0.056)
Constant	1.446†	(0.752)	2.023*	(0.979)
Observations	1114		1114	

Note:

1. *$^{\dagger}p < .10$; *$p < .05$; ** $p < .01$; *** $p < .001$*
2. *ALEKS scores were imputed for those students who had missing scores on ALEKS. 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 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 average exam scores. We found that both the lectures and teaching assistant led activities had a positive and significant relationship with average exam scores. It should be noted that when these other course components were added to the HLM model, the variables that were originally significant in this model, such as platform average score and platform total hints requested, were still significant, but their magnitude of association with average exam scores was reduced after accounting for participation in these other course components (see Table 1)[2].

FCI Gain Scores

Table 2 shows the results for the HLM analysis with FCI gain 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 1. As mentioned earlier, we used FCI gain scores since this would take into consideration the initial level of FCI pre-test scores. In addition, we examined the results when FCI post-test was the outcome measure (Appendix C).

The HLM model in Table 2 shows that the baseline characteristics that were significantly related to FCI gains include being female and being white, while ALEKS scores were no longer significant. This might be because the outcome measure was FCI gain scores, which had already taken into account prior achievement. The lecture course component was found to be positively and significantly related to FCI gains, but teaching assistant led activities were not.

Platform average score and platform total time were significantly associated with FCI gains but not platform total hints. As mentioned earlier, for platform total time, we cannot determine when students were actively engaged while logged in. Hence we have to view the significant finding for platform total time with caution. The platform predictor that was consistently significant across both outcome measures was platform average score. The higher the platform average score, the greater the FCI gain. That is, for an increase in the platform average score, the FCI gains increased by 0.2 percentage points.

---

[2] The correlations among the platform average scores, the lecture scores, and the scores from teaching assistant led activities ranged from 0.45 between platform average scores and lecture scores to 0.50 between platform average scores and teaching assistant led activities. These moderate correlations help to explain why the platform average score is still significant but with reduced magnitude of association. The correlations among platform total hints, lecture scores, and the scores from teaching assistant led activities are lower, with correlation of 0.28 between total hints and lectures scores and correlation of 0.13 between total hints and teaching assistant led activities.

Table 3: HLM Results with FCI gain scores as the outcome measure

	HLM		HLM Including Other Course Components	
	Coefficient	Std. Error	Coefficient	Std. Error
Platform Variables				
Platform Average Score	0.356***	(0.095)	0.223*	(0.104)
Platform Total Hints	0.022*	(0.011)	0.016	(0.011)
Platform Total Time	0.238**	(0.088)	0.234**	(0.087)
Baseline Characteristics				
Female	-6.465***	(1.778)	-6.638***	(1.766)
White	8.973***	(1.592)	8.372***	(1.593)
First Generation College Status	1.562	(4.688)	-0.344	(4.684)
ALEKS Score (Standardized)	0.850	(0.886)	0.899	(0.882)
Other Course Components				
Lecture			0.187**	(0.057)
Teaching Assistant Led Activities			0.129	(0.127)
Constant	-5.450***	(1.350)	-5.199***	(1.342)
Observations	961		961	

Note:

1. *$^{\dagger}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$*
2. *ALEKS scores were imputed for those students who had missing scores on ALEKS. 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 FCI gain scores

When examining how other course components might play a role in the relationship between Mastering Physics and FCI gain scores, we found that participation in lectures (but not teaching assistant led activities) had a positive and significant relation with FCI gains. As with the results for average exam scores in Table 2, when variables on other course components were included in the HLM analysis for FCI gain scores, the variables that were originally significant in the HLM model, such as platform average score and platform total time, were still significant. However, their magnitude of association with FCI gain scores was reduced after accounting for participation in these other course components (see Table 2).

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 the models, including additional course components in Tables 1 and 2, the significance results are identical to the ones without the multiple comparison adjustment, except the relation between hints and exam scores in Table 1.

Missing Data

Missing data in this study was addressed through imputation of the ALEKS score. Approximately 1,200 students were enrolled in the course across the two semesters. However, the sample sizes used in the HLM analyses were at least 961, indicating that more than 80% of the students who were enrolled in the course were used in the analysis. This did not indicate a major problem with missing data after imputation on missing data for the ALEKS scores was done.

Implications Regarding Claims on Platform Variables and Outcomes

Based on the HLM results in Tables 1 and 2, 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 10 to round up to whole numbers. For example, a unit (or 10%[3]) increase in Mastering Physics homework grade is linked to a 0.4[4] (or 4%) 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 2% increase in FCI gains.

As mentioned previously, homework assignments using Mastering Physics were among 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.

---

[3] MasteringPhysics homework grades and exam scores were on a percent scale as reflected in the claim statements.

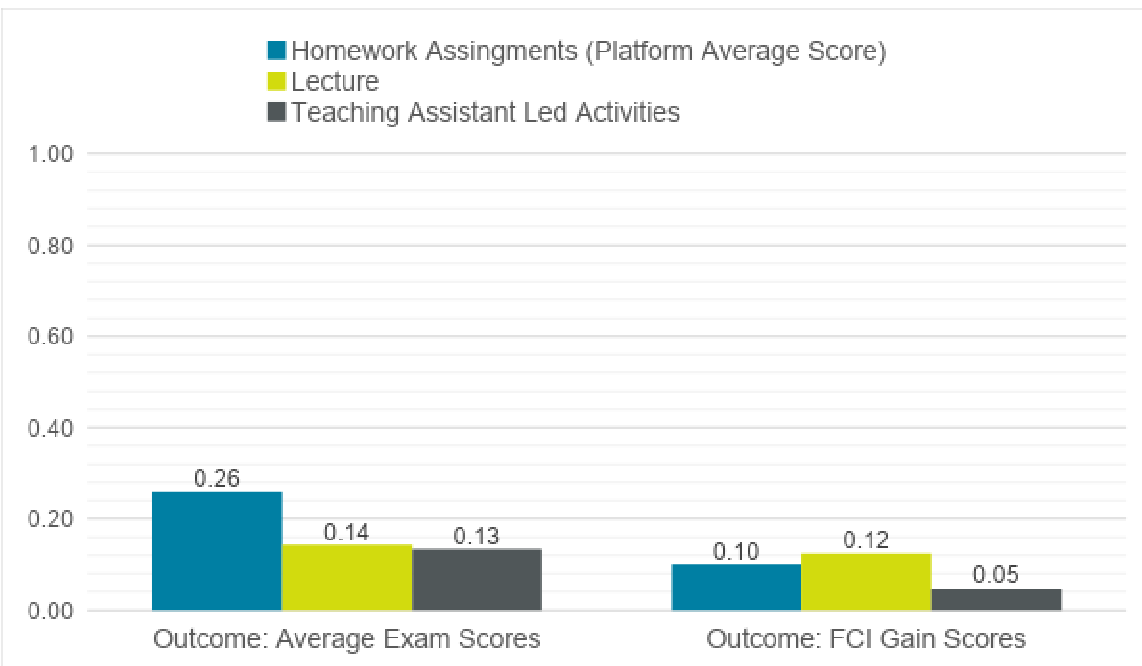
[4] 0.4 was rounded up from the regression coefficient of 0.363.

In order to do this, we needed to examine the standardized coefficients from the HLM models, which are the effect sizes. This is to ensure that the unit of comparison is similar across all course components. Figure 5 shows the effects size of each of the course components. Appendix D shows the standardized coefficients of all variables included in the HLM analyses for both outcome measures – average exam scores and FCI gains.

When the outcome measure was the average exam scores, the effect size for platform average score is about twice as large as that for lecture and teaching assistant led activities. In other words, an increase in achievement on the homework assignments is associated with increases in average exam scores that are twice as high as for other course components. For FCI gains, the effect sizes for the platform average score and lecture are about the same, indicating that increases in the scores for homework assignments and lecture are associated with the same increase in FCI gains.

The effect size for the platform average score when the outcome was average exam scores is twice as large as the effect size when the outcome measure was FCI gains. The correlation between average exam scores and FCI gain scores was found to be 0.34 which is not a very high correlation. It could be that homework assignments were better aligned with the course exams than with the FCI test.

Figure 5: Effect sizes (standardized coefficients) for the various course components



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.

Discussion

Data for this report came from two semesters of an introductory physics course taught by two instructors at Penn State University. 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 FCI. In this study, we wanted to support the validity of any claims we can make about the use of Mastering Physics by accounting for and statistically controlling for outside factors that might affect student achievement, 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 achievement and first generation college status, by statistically controlling for these confounding variables in our analysis.

We hypothesized that higher levels of Mastering Physics usage, such as higher number of hints requested by students in Mastering Physics, would be linked to higher achievement on the course exams and FCI. Higher levels of Mastering Physics usage 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.

The results provided some support for our hypotheses. We found that the platform average score was positively and significantly associated with average exam scores and FCI gain scores. And the effect size for the platform average score (performance in homework assignments) was found to be twice as much as the effect sizes for performance in other types of course components, when the outcome measure was average exam scores. Doing well in homework assignments appeared to be more strongly associated with achievement in the course exams than achievement in lectures and teaching assistant led activities. However, the effect size for achievement in homework assignments was found to be smaller when the outcome measure was FCI gains, indicating the possibility that Mastering Physics homework assignments might be more aligned to course exams than the FCI test.

Although the results supported our hypothesis for platform average score, there were mixed results for platform total hints. These were found to be positively and significantly related to average exam scores, but not for FCI gains. When the outcome measure, FCI post-test, was used instead, platform total hints became significant again (see Table C1 in Appendix C). There could be various explanations for this. FCI post-test measures the level of proficiency at the end of the course, while FCI gain measures the change in level of proficiency. That is, students who did well in FCI post-test might be using more hints, as evidenced by the positive significant result. However, if these students also scored high on the FCI pre-test (given that the correlation between FCI pre-test and post-test is high at 0.712), then their gain would not be high due to ceiling effect. This can explain the non-significant result when the outcome was FCI gain.

We explored further the relationship between platform total hints and average exam scores, which was found to be significant. This was done by dividing the distribution of total hints equally into five categories, quintiles. Quintiles are useful in determining the nature of the relationship, such as whether it is linear. Our quintile analysis showed that there might be an increasing monotone relationship between total hints and average exam score, and that this relationship is likely to be diminishing returns. That is, with increasing total hints requested, the increase in predicted average exam score might become smaller. Detailed results of the quintile analysis for total hints are presented in Appendix E.

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 FCI, 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 only one type of physics course over two semesters only at one school, so the extent of generalizability of the findings from this study might be another limitation.

Implications of Findings for Product Implementation and Further Research

The findings from this study are only a 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 there can be other types of interactions that can affect student achievement. In this study, 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 instructors in the course. As mentioned, we were not able to differentiate between the time when students were actively engaged while logged in to 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 MasteringPhysics could also make use of more robust research methods. For example, they could use ana 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, to increase generalizability. 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.

Pearson

References

Allison, P. (2000). Multiple imputation for missing data: A cautionary tale. *Sociological Methods and Research, 28*, 301-309.

Bureau of Labor Statistics (May 2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review*. Retrieved from: https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science 1*, 73-105.

Drew, C. (2011, November 4). Why science majors change their minds (it's just so darn hard). *The New York Times*. Retrieved from http://www.nytimes.com/2011/11/06/education/edlife/why-science-majors-change-their-mind-its-just-so-darn-hard.html

Greene, R. L. (2008). Repetition and spacing effects. In J. H. Byrne (Ed.), *Learning and memory: A comprehensive reference, Vol. 2* (pp. 66-78). Oxford, UK: Academic Press.

Marx, J. D. & Cummings, K. (2007). Normalized change. *American Journal of Physics,* 75(1), doi: http://dx.doi.org/10.1119/1.2372468.

Raudenbush, S. W. & Bryk, A. S. (2002). Hierarchical linear models: Applications and data analysis methods (2nd ed.). Thousand Oaks, CA: Sage.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences, 13*(3), 273-304.

Roediger, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science, 1*(3), 181-210.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153-189.

Van der Kleij, F. M., Feskens, R. C., & Eggen, T. J. (2015). Effects of feedback in a computer-based learning environment on students' learning outcomes: A meta-analysis. *Review of Educational Research, 85*(4), 475-511.

von Hippel, P. T. (2007). Regression with missing Ys: An improved strategy for analyzing multiply imputed data. *Sociological Methodology*, *37*(1), 83-117.

What Works Clearinghouse (March, 2016). *Applying the What Works Clearinghouse standards to postsecondary research*. Washington, DC: Department of Education, Institute of Education Sciences.

Pearson

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.

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	16 (Added)	2025

		identifier) as two separate observations		
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 where students take second physics course	2009	Drop cases of students in classes outside of research plan, such as students in second (not introductory) physics class	697	1312
Drop cases with duplicate IDs	1312	13 students took same course twice (i.e. Fall 2015 and Fall 2016) and we are unable to match the platform data up correctly	26	1286
Drop case with improperly deidentified data	1286	1 observation had an ID that didn't match up with the rest of the data and was dropped	1	1285
Drop cases for students who attend class exclusively meant for physics major students	1285	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.	70	1215
4. Exclusion Criteria for Analysis				
Drop cases from final analysis where not only ALEKS score is missing but also data is missing on all variables used in imputation (SAT Math score, GPA in Math 140, GPA in Math 141, and GPA in Chem 110 classes)	1215	Cases where student is missing data on ALEKS score and all variables that are used for the imputation model are deleted before running the analysis	100	1115

Drop cases with missing outcome variable	1115	Cases where student is missing data on outcome variable are deleted before running the analysis	1 (Exam Score); 154 (FCI change score)	1114 (Exam Score); 961 (FCI change score)

Appendix B. Imputation Methodology Used for ALEKS Scores

Multiple imputation was used to account for the 41% of students in the analytic sample that had missing values for ALEKS scores. Multiple imputation is a statistical technique often used to analyze data sets for which some entries are missing. Application of this technique requires three steps: 1) imputing missing entries of incomplete datasets multiple times (resulting in a number of datasets), 2) analyzing each of the imputed datasets separately, and 3) pooling or integrating the results of the analysis for each of the datasets into a final result. Multiple imputation generally produces a better estimate of the analytic models used in the available data due to the reduction of potential bias and increase in statistical power that may occur relative to using pairwise deletion.

For the purposes of this paper, 50 datasets were imputed. In the models, the important covariate that would be imputed for missing data was the ALEKS score. Specifically, predictive mean matching was used to impute ALEKS scores for the missing observations. Baseline demographic variables and outcome variables from the analytic model were used in the imputation model. Additionally, variables that were available in the data but not used in the analytic models were used as auxiliary variables in addition to the aforementioned variables to provide a better estimate for the imputed ALEKS scores. These auxiliary variables were not included in the analytic models because they would have shared the same intent as an alternative measure for prior achievement and were highly correlated with ALEKS score. Including these variables in the analytic models would have introduced collinearity and biased the estimates. However, including these highly correlated variables as auxiliary variables helped provide a better estimate for ALEKS score. These auxiliary variables included SAT Math scores, and grades in three prerequisite classes – Mathematics 140, Mathematics 141, and Chemistry 110.

Following the creation of the imputed datasets, observations where the outcome variables were originally missing and then imputed were dropped from the analysis, following the multiple impute and delete (MID) approach (Allison, 2002; von Hippel, 2007). This approach was taken as the observations with missing data on the outcomes still had non-missing data on the baseline characteristics, covariates, and ALEKS score which would improve the accuracy of the imputation model for ALEKS score.

After the creation of these 50 datasets, the analytic model was run on each of these 50 datasets and the results were then pooled to create a final result. Tables C1 and C2 present the pooled results across these 50 datasets. Each model in both tables had its own multiple imputation process.

Appendix C. HLM Results for FCI Post-Test

Table C1: HLM results with FCI post-test scores as the outcome measure

	HLM		HLM Including Other Course Components	
	Coefficient	Std. Error	Coefficient	Std. Error
Platform Variables				
Platform Average Score	0.198***	(0.047)	0.123*	(0.051)
Platform Total Hints	0.016**	(0.005)	0.013*	(0.005)
Platform Total Time	0.157***	(0.044)	0.154***	(0.044)
Baseline Characteristics				
Female	-4.075***	(0.935)	-4.286***	(0.928)
White	4.694***	(0.793)	4.384***	(0.793)
First Generation	2.537	(2.374)	1.475	(2.370)
ALEKS Score (Standardized)	0.944†	(0.482)	0.999*	(0.471)
FCI Pretest Score	0.625***	(0.021)	0.617***	(0.021)
Mediators				
Lecture			0.099***	(0.028)
Teaching Assistant Led Activities			0.078	(0.064)
Constant	-2.368***	(0.671)	-2.186**	(0.667)
Observations	1002		1002	

*†p < .10; *p < .05; ** p < .01; *** p < .001*

When the outcome measure was FCI post-test scores, all the platform variables were significantly related to FCI post-test scores. That is, the higher the platform average score, the platform total hints, and platform total time attained by the student, the higher the FCI post-test score. Participation in lectures was also found to be positively and significantly associated with FCI post-test scores.

Appendix D. HLM Models with Standardized Coefficients

Table D1: HLM models with the standardized coefficients (effect sizes)

	Average Exam Scores		FCI Gain Scores	
	Standardized Coefficient	Std. Error	Standardized Coefficient	Std. Error
Platform Variables (Standardized)				
Platform Average Score	0.259***	(0.038)	0.101*	(0.047)
Platform Total Hints	0.083†	(0.039)	0.057	(0.039)
Platform Total Time	-0.040	(0.040)	0.116**	(0.043)
Baseline Characteristics				
Female	-0.529***	(0.060)	-0.258***	(0.069)
White	0.042	(0.053)	0.325***	(0.062)
First Generation College Status	-0.213	(0.166)	-0.015	(0.182)
ALEKS Score (Standardized)	0.226***	(0.030)	0.029	(0.036)
Other Course Components (Standardized)				
Lecture	0.143***	(0.032)	0.124**	(0.038)
Teaching Assistant Led Activities	0.133***	(0.033)	0.047	(0.046)
Constant	0.125*	(0.061)	-0.202***	(0.052)
Observations	1114		961	

Note:

1. *†p < .10; *p < .05; ** p < .01; *** p < .001*
2. *ALEKS scores were imputed for those students who had missing scores on ALEKS. Variables used to impute the ALEKS scores include SAT Math and grades obtained in prerequisite math or chemistry courses.*

Appendix E. Further Exploration of the Relationship between Total Hints and Average Exam Scores

Table E1: HLM models for average exam scores with total hints in quintiles

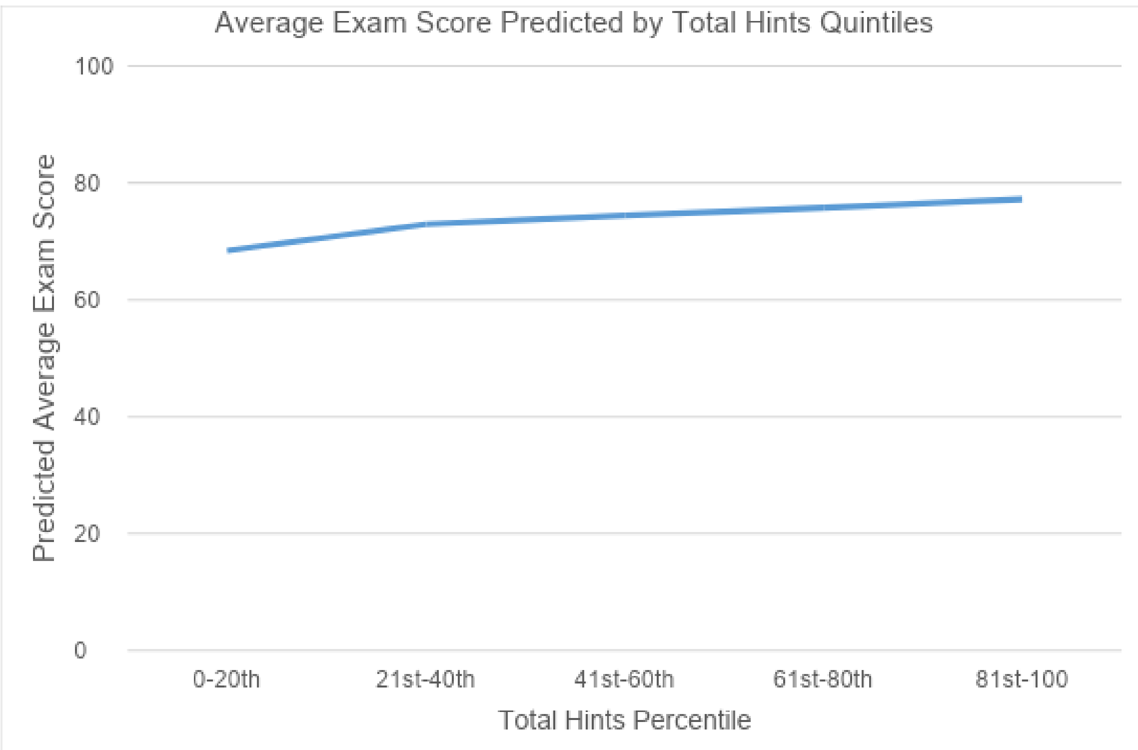
	HLM		HLM including Other Course Components	
	Coefficient	Std. Error	Coefficient	Std. Error
Platform Variables				
Platform Average Score	0.547***	(0.047)	0.370***	(0.052)
Quintiles of Total Hints *(Bottom 20% as Reference Category)*				
21st to 40th Percentile	4.718***	(1.339)	4.377***	(1.294)
41st to 60th Percentile	4.660***	(1.408)	4.065**	(1.364)
61st to 80th Percentile	6.209***	(1.474)	5.328***	(1.447)
81st to 100th Percentile	6.927***	(1.710)	6.535***	(1.676)
Platform Total Time	-0.067	(0.058)	-0.086	(0.056)
Demographics				
Female	-8.155***	(0.989)	-8.362***	(0.964)
White	0.905	(0.878)	0.240	(0.862)
First Generation	-2.859	(2.723)	-3.812	(2.680)
ALEKS Score (Standardized)	3.630***	(0.501)	3.688***	(0.489)
Other Course Components				
Lecture			0.128***	(0.030)
TA-Led Activities			0.228***	(0.055)
Constant	-2.874*	(1.284)	-1.928	(1.436)

Observations	1114	1114

Note:

1. *†p < .10; *p < .05; ** p < .01; *** p < .001*
2. *ALEKS scores were imputed for those students who had missing scores on ALEKS. Variables used to impute the ALEKS scores include SAT Math and grades obtained in prerequisite math or chemistry courses.*

Figure E1: Total hints in quintiles and the predicted values in average exam score from the HLM analysis



The increase in the predicted average exam score after the 21st-40th quintile in total hints is smaller than the increase before the 21st-40th quintile, indicating diminishing returns in the total hints on predicted average exam score.

Appendix F. Table 1 and 2 p-values adjusted for multiple comparison using Benjamini-Hochberg method (q-values)

	Exam Scores		FCI Change Scores	
	Original *p*-value	Adjusted *q*-value	Original *p*-value	Adjusted *q*-value
Platform Variables (Spring 2016)				
Platform Average Score	0.0000	0.0000	0.0313	0.0313
Platform Total Hints	0.0306	0.0611	0.1324	0.1324
Platform Total Time	0.3338	0.3338	0.0073	0.0145
Baseline Characteristics				
Female	0.0000	0.0000	0.0002	0.0002
White	0.4485	0.4485	0.0000	0.0000
First Generation	0.2142	0.4285	0.9414	0.9414
ALEKS Score (Standardized)	0.0000	0.0000	0.3084	0.3084
Other Course Components (Spring 2016)				
Lecture	0.0000	0.0000	0.0011	0.0011
Teaching Assistant Led Activities	0.0000	0.0001	0.3107	0.3107

Appendix G. Course Syllabus

General Physics Mechanics (Calculus Based)

PHYS 211: General Physics Mechanics

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. Textbooks may be purchased either in the hard cover version or as a soft cover "split". The hardcover version contains all the material covered in Phys 211212.

The soft cover "split" is the custom edition available in the bookstore, which is bundled with the Mastering Physics online homework system described below.

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 Lectures 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 study of the basic concepts of mechanics: motion, force, Newton's laws, energy, collisions, and rotation.

Course Objectives

Upon completion of PHYS 211, students should be able to demonstrate a mastery of:

1. Relating position, velocity, acceleration and time using kinematics relationships
2. Using vectors
3. Forces and Newton's Laws of Motion
4. Rotational Motion
5. Conservation laws
6. Oscillations and Waves

For a more detailed list of course objectives, please see the Exams folder.

Tentative Schedule

See the Calendar and 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 PHYS 211L (lecture) and PHYS 211R (lab/recitation) to earn a grade in this course.

Problem Set assignments – In general, there will be two problem set assignments per week. The due date and time for each assignment appears on MasteringPhysics. They will typically be due Tuesday and Friday evenings.

We will be using an online computer grading system called MasteringPhysics 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

Corequisite: MATH 140

Grading Policy

Your grade in the course will be based on your performance in the labs, in recitation, on the problem set 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%

Final letter grades for the course will be based on an absolute scale. The course score will be rounded up 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 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 up to the nearest integer at the end of the course. You are responsible for verifying all of your scores (with the exception of the final exam score) before the final exam for the course.

Attendance Policy

Lecture

There will be two lectures a week, which will be used primarily to introduce principles and concepts. The pace will be very fast. We will be covering approximately one chapter per lecture. Thus missing one lecture amounts to missing an entire chapter of material. Attendance is strongly encouraged. Students should read the relevant material from the textbook before the lecture. Lecture will teach you how to think like a physicist, while recitation will teach you to solve problems. Both are important, and you can't do one well without knowing how to do the other. We will use i>clickers in class for three different types of questions in lecture: (1) reading quizzes 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 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 and your participation. 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 makeup 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 211L 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 312 Osmond. Your meeting time is determined by your 211R section number. You must attend the laboratory section in which you are scheduled no switching is permitted. The experimental portion of the laboratories are designed to provide you with hands on experience with the material being investigated in class. Teaching assistants lead the laboratory sessions and act as your guides as you explore the material. Students work collaboratively in three member lab groups to carry out the experiments. The lab activities will be posted on the course website. During the lab session, each group prepares a single writeup, addressing specific points of the experiments. This writeup must be submitted by the group before the end of the laboratory session. If a lab section is missed for a legitimate reason (see section below), it is your responsibility to promptly contact your teaching assistant (TA) and submit a Valid Excuse Form online (see the Valid Excuse Policy section of the syllabus).

Recitation

You must attend the section for which you are registered. Most of your exposure to problem solving will come through recitation, not through lecture. You will work on the recitation activities in groups of 3. Recitations will give you invaluable problem solving experience. During the summer session, there are more recitations, and they are longer in duration, than the regular semester, giving you more time to practice.

Attendance is mandatory for the whole recitation. If a recitation section is missed for a legitimate reason (see "Valid Excuse Policy" below), it is your responsibility to promptly contact your teaching assistant (TA) and submit a Valid Excuse Form online (see the Valid Excuse Policy section of the syllabus)

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.

Exam Policy

There will be two midterm exams and a final exam. All exams will be cumulative and closed book. Relevant physical constants and formulae will be provided for you. You may ONLY bring a standard scientific type or graphing calculator, you may not use any programs on your calculator which are not manufacturer installed. Cellular phones, electronic organizers, tablet computers, any other electronic device or additional paper are not allowed.

The exams will be based on the assigned reading in the textbook, the material covered in lecture, the homework assignments, the recitations, and the laboratories. The exams will focus on material cover since the last exam but are cumulative. 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 ademic 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.

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.

In order to receive consideration for course accommodations, you must contact ODS and provide documentation (see the 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!

Students are NOT permitted to attend any laboratory or recitation section other than the one in which they are scheduled. Failure to attend the proper section could result in the loss of grade for that activity.

Problem Sets

You must complete the Problem sets as scheduled. The Problem sets 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

Valid reasons to be excused from an evaluative event (i.e. a graded class activity or a homework assignment) include illness or injury, family emergencies, university approved curricular and extracurricular activities, and religious holidays. 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 4920

* 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 extracurricular 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).

Resources for Help

For help on physics outside of class, you should attend the Physics Department Learning Resource Center or the office hours of any teaching assistant for the course, not just your own. The course lecturer also has office hours. Links for these are in the "Resources" tab of Angel

Announcements about the course will appear on Angel.