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Technical Report

A study of Mastering Biology use in a foundational biology course

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Executive summary

Overview of Mastering Biology

This study investigates the efficacy of Mastering Biology, an online tutorial, homework and assessment tool for undergraduate biology education. In the context of a foundational biology course at a public university, the study examines how engagement with Mastering Biology homework assignments relates to performance in course exams.

Mastering Biology homework assignments are assembled from a bank of questions and problems in a variety of formats that provide students with the practice needed to master foundational concepts and skills in biology. Many questions are accompanied by optional hints. Students get immediate feedback as they answer each question. They can use this feedback to try the question again. These features of Mastering Biology's homework assignments align with several learning science principles, suggesting their use should be associated with improved learning and higher scores in course exams.

Student 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 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 select a different major or drop out of college. Although a number of factors are likely to be at work, one reason presented is the difficulty of STEM courses that often lack adequate support for students struggling with their coursework (Drew, November 4, 2011). Mastering Biology addresses these issues by providing learners with an online learning environment that is rich in support, setting them up for successful completion of their biology course.

Intended outcomes and study sample

The primary goal of this study was to assess the relationship between Mastering Biology use and student learning. The two measures used were student engagement on the Mastering Biology platform (time spent, hints used and average score on the homework assignments) and achievement in the course exams. Average course exam scores were calculated based on three interim exams throughout the semester and a final exam at the end of the semester.

This study was carried out during the Spring 2017 semester in a foundational biology course focused on Mendelian and population genetics, evolution and ecology. The course was taught by a single instructor in a North American, state-related, land-grant doctoral university. The course provides a foundation for subsequent core and advanced courses in the university's Department of Biology. About 230 students were enrolled in this course in Spring 2017, and approximately 150 students agreed to participate in the study. Mastering Biology was primarily used for homework assignments.

Research questions

1. What are the student factors (e.g. prior achievement, full-time status, STEM major, test anxiety and confidence in course, parent education, Mastering Biology usage patterns) that are related to student achievement?
2. To what extent are Mastering Biology usage patterns throughout the course (e.g. time spent, use of hints, progress in homework assignments, etc.) related to student achievement? Is the relationship robust after controlling for student characteristics?

Key findings

Based on results from a regression model, being a student with a prior grade point average (GPA) of at least 3.5 on a 4.0 scale before Spring 2017 as well as being a full-time student were both significantly related to higher average exam scores, while high levels of test-taking anxiety was related to a decrease in academic performance.

Looking at the relationship between Mastering Biology platform variables and achievement, the following claim can be made:
Averaging at least 90% or better on Mastering Biology homework assignments is associated with a 9% increase in exam scores.
Students on this course were allowed multiple hints and multiple attempts on the homework assignments. This may account for the high average scores for Mastering Biology homework, as well as the fact that only very high homework performance (i.e. in the 90% or better range) was associated with higher exam scores. So, through multiple attempts and availability of hints, students may have been able to earn relatively high homework scores without necessarily mastering course content, and perhaps only the highest performers ultimately mastered the content material. Future research should examine this hypothesis.

We also found that total time spent on the platform and the number of hints accessed by a learner were not significantly related to exam scores. One limitation of the measure of time spent used in this study is that cannot distinguish between active time spent engaged in the course materials versus idle time simply logged into Mastering Biology, which could explain the null finding. In addition, it may be that spending more time on homework and requesting more hints, by themselves, are not enough to ensure mastery of the course material. Struggling learners who are conscientious may spend more time and request more hints than learners with a good grasp of the material. But low-performing learners who are not conscientious may not be motivated enough to spend extra time and open hints. This is another area for future research to explore.

Limitations

This study has a number of limitations. First, the research design only allows us to make correlational claims and not causal claims about Mastering Biology and achievement. We therefore cannot know whether higher achievement in Mastering Biology homework assignments would actually lead students to improve their achievement in their course exams or whether another factor is at play. In light of the fact that we could not account for all possible confounding factors, we cannot rule out the influence of all the confounding factors on students' achievement in the course. The study also used data from only one biology course in a single semester at one university, with the instructor implementing Mastering Biology tailored to her course. This limits the potential generalizability of the findings to a different setting.

Recommendations and next steps

The findings from this study are a step towards understanding how the use of Mastering Biology is associated with student achievement. One direction for future research suggested by the findings of this study is to examine whether other types of interaction can affect student achievement. In this study, we only examined the number of hints and time spent in Mastering Biology, alongside the student's average score across all the homework assignments given by the instructor in the course. As mentioned earlier, a problem with the time spent data is that we cannot differentiate between time actively engaged or simply logged in. There may be other types of interaction within Mastering Biology that could be a more accurate measure of a student's level of engagement, such as the number of solution checks requested by students while completing homework assignments. This data wasn't available for this study.

Further studies on Mastering Biology 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. This could 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, they could control for a wider array of student variables to more thoroughly adjust for confounding factors that might also influence achievement in a biology course other than use of Mastering Biology.

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Introduction

Background foundational research

This study investigates the efficacy of Mastering Biology, an online tutorial, homework and assessment tool for use in undergraduate biology education. The study specifically examines the relationship between students' engagement with and performance in Mastering Biology homework assignments and performance in independent course exams.

Mastering Biology homework assignments are based on a large bank of assessment items in a variety of formats, including multiple choice and matching questions, concept mapping and diagram labeling exercises. Many questions are accompanied by optional hints to help students who might be struggling. Students receive immediate, response-specific feedback. Instructors can allow students to re-attempt questions they answer incorrectly, so that students can use the feedback to try again. The optional hints, response-specific feedback and multiple attempts in Mastering Biology homework are intended to provide a personalized learning experience that helps students learn from their mistakes and achieve mastery of biology concepts and skills at their own pace. This student-centered approach to learning generally aligns with the recommendations made by the American Association for the Advancement of Science's *Vision and Change in Undergraduate Biology Education* (2011).

Key features of the research into learning design for Mastering Biology

The features of Mastering Biology homework assignments embody several learning science principles, such that engagement with and performance in Mastering Biology homework should facilitate learning and be positively associated with performance in course exams, even after controlling for several variables that are likely to affect exam performance. We will now briefly review these principles.

Active, constructive and interactive learning

Mastering Biology homework assignments embody what are known as *active*, *constructive* and *interactive* approaches to learning (Chi, 2009). Each of these approaches has been shown to be more effective for learning than passive approaches, in which a learner's sole activity is the intake of information (e.g., listening to a lecture). Active learning is characterized by doing something during learning, and it ranges widely from taking notes during a lecture to searching a textbook for information to handling lab equipment. Constructive learning refers to activities in which a student produces a novel idea or other output that goes beyond previously encountered information, for example the solution to a novel problem. Interactive learning involves a back-and-forth interaction between the student and another 'intelligent entity', either another person or an intelligent tutoring system. Research demonstrates that each of these approaches to learning is more effective than passive approaches, with efficacy increasing as learning activities progress from active to constructive to interactive forms (Chi, 2009).

Mastering Biology homework assignments support active, constructive and interactive approaches to learning. For active learning, students perform a range of actions to answer questions and solve problems, such as visually scanning diagrams, consulting the textbook or working through problems with pencil and paper. For constructive learning, students solve novel problems, for example by creating a concept map or predicting the outcome of a hypothetical experiment. Finally, for interactive learning, students are given hints and feedback that they can consider and incorporate into their learning — this is also the case for further attempts on incorrectly answered problems.

Testing effects

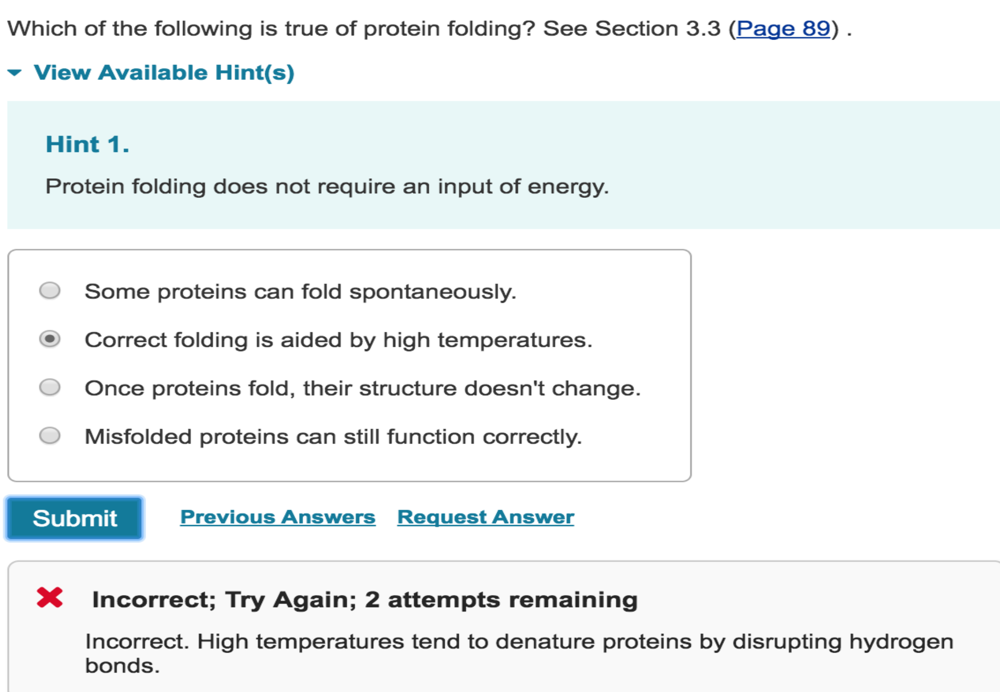
Being tested on information improves learning and memory more than simply reviewing that same information (e.g., by rereading the textbook or reviewing notes). This testing effect is a well-established psychological phenomenon, having been demonstrated in a large number of laboratory and classroom settings (Roediger & Karpicke, 2006). Testing is believed to support learning by requiring retrieval of information from memory, thereby strengthening the ability to remember that information later. Mastering Biology homework requires such memory retrieval, both in answering questions that require basic recall of facts and in solving novel problems, which themselves require recalling foundational information necessary to develop a solution to the problem. Engaging in Mastering Biology homework assignments, therefore, should produce testing effects that enhance memory and promote higher scores in subsequent exams.

It is important to note that the testing effect requires the successful retrieval of correct information, because memory for correct information cannot be strengthened if incorrect information or no information is retrieved (Roediger & Butler, 2011). Students who successfully retrieve correct information are more likely to answer a question correctly than students who do not retrieve correct information, meaning that students who perform better on homework assignments should experience greater testing effects and should perform better in subsequent exams. This would include students who initially respond to a question incorrectly but successfully retrieve correct information when they try the question again. In this way, re-attempting a question initially answered incorrectly until the correct response is determined can promote learning. Consistent with this idea, research suggests that testing effects are enhanced when memory retrieval takes more effort (Pyc & Rawson, 2009).

Feedback

Providing students with feedback on their performance is an important component of learning and, in fact, is a major component of interactive learning. At a minimum, feedback must indicate to the student whether a response is correct or incorrect. Research on the testing effect has shown that, although the benefits of testing can be achieved without feedback, providing the correct answer enhances learning, particularly for questions that were answered incorrectly (Roediger & Butler, 2011). In line with this principle, Mastering Biology homework assignments reveal the correct answers to students at the completion of each assignment. Additional research has shown that feedback that explains or otherwise elaborates on the correctness of a response is more effective than feedback that indicates *only* correctness (Schute, 2008; Van der Kleij, Feskens, & Egge, 2015). Mastering Biology provides this type of elaborative, response-specific feedback immediately after a student responds to each question — for example, feedback might explain why the chosen response is incorrect or direct the student's attention to a particularly important component of the question. This feedback can guide a re-attempt of the question, helping students learn from their mistakes.

Figure 1: A multiple-choice question in Mastering Biology



Note: The optional hint is revealed above the question. An incorrect response has been chosen, and elaborative, response-specific feedback is provided below the question.

Scaffolding

Many Mastering Biology questions provide optional hints that students can consult when struggling to answer a question. These hints are a form of *scaffolding* that gives students support to help them achieve what they otherwise might not be able to achieve. Such scaffolding in technology-enhanced learning environments shows substantial promise for improving student learning (Sharma & Hannafin, 2007; Reiser, 2004). According to Reiser (2004), scaffolding can serve two main functions: structuring and problematizing. A structuring scaffold simplifies a complex or open-ended problem, while a problematizing scaffold encourages students to notice unresolved issues or engage with complexity that they might otherwise overlook.

Mastering Biology hints include both structuring and problematizing scaffolds. For example, there are structuring scaffolds when reminding students of key information or indicating the first step to take in solving a problem (e.g., a hint that states: "Consider the enzyme's name to deduce its function."). There are problematizing scaffolds in the form of leading questions that encourage students to grapple with relevant complexity or to notice key ideas (e.g., a hint that asks: "What is accomplished when a gene is cloned?") Some problematizing scaffolds in Mastering Biology pose questions that accept student input in response and provide their own response-specific, elaborative feedback. See Figure 1 for an example of a hint that provides structuring scaffolding.

In light of Mastering Biology's alignment with these learning science principles, we hypothesize that engagement with Mastering Biology supports learning and, as a result, should be associated with higher scores in biology course exams[1]. In this study, Mastering Biology measures include time spent logged into the platform, students' use of hints, and homework scores. There is reason to believe that increases in these measures should capture, in part, greater learning due to the learning science principles reviewed above.

First, although time logged into the platform is a coarse measure of engagement (i.e., a student can be engaging in any number of activities while logged in), it stands to reason that, on average, a student who spends more time engaging with Mastering Biology questions, hints and feedback will be logged in for more time than a student who spends less time engaging with these features. Next, students who access more hints experience a greater degree of scaffolding and, when using the hints to modify their approaches to problems, engage in constructive learning. Finally, higher scores in homework assignments can be driven not only by students' mastery of content before attempting the homework but also by students' development of mastery while completing the homework. Most students will not be able to answer all questions correctly on the first try. However, a student who successfully re-attempts a question is more likely to have benefitted from the response-specific feedback and successful memory retrieval (i.e., testing effect) than a student who fails on another attempt or does not re-attempt the problem.

1 As discussed below, this study uses a correlational design, so any associations observed cannot be taken to imply causation.

Therefore, higher homework scores should be driven, in part, by successful re-attempts of questions, which themselves should promote learning. In fact, this is a key component of Mastering Biology: supporting each student's development of mastery through re-attempting questions until they can answer those questions successfully.

The present study

The primary goal of this study was to assess the relationship between use of Mastering Biology, as determined by student engagement on the Mastering Biology platform, and student learning, as measured by student achievement in course exams. Additionally, the current study examines the extent to which student characteristics and psychological factors, such as test-taking anxiety and confidence, are related to academic performance.

This study examines Mastering Biology platform use in a Spring 2017 foundational biology course focused on organismal biology, and it addresses the following research questions:
What are the student factors (e.g. prior achievement, full-time status, STEM major, test anxiety and confidence in course, parent education, Mastering Biology usage patterns) related to student achievement?
To what extent are Mastering Biology usage patterns throughout the course (e.g. time spent, use of hints, progress in homework assignments, etc.) related to student achievement? Is the relationship robust after controlling for student characteristics?

A range of student factors are known to be associated with student achievement. This study aimed to identify the unique contribution of Mastering Biology use to student achievement, independent of other confounding factors known to be related to student achievement. We did this by collecting data on, and adjusting (or statistically controlling) for, as many extraneous factors as possible that might affect student achievement. Controlling for these extraneous factors would reduce bias in the analytic models which, in turn, would not only strengthen the models but also further support the validity of any claims we can make about the use of Mastering Biology.

Two important confounding factors that we were able to control for in the analysis were students' socioeconomic status, as measured by parent education, and prior achievement, as measured by student grade point average (GPA) prior to Spring 2017 (What Works Clearinghouse, 2016). This design is similar to the case-control design frequently used in health studies, where one statistically controls for additional factors that might influence the outcome.

Our main hypothesis was that higher use of Mastering Biology, as reflected in greater level of student engagement, would be linked to higher achievement in course exams. The logic behind our hypothesis is that increased engagement in Mastering Biology could provide students greater exposure, deeper processing, and mastery of biology content as they complete the homework assignments. This would result in greater performance in course exams. We also hypothesize that performance in Mastering Biology homework would be positively associated with achievement in the course exams. It is plausible that when students master the course materials, as reflected in their performance on the homework, they will also tend to perform better in exams.

Furthermore, we believe that psychosocial factors such as test-taking anxiety and confidence may have some significant relations to performance. For example, high levels of test-taking anxiety can be related to poor academic performance (Cassady & Johnson, 2002; Hembree, 1988) while high levels of confidence in academic abilities may be related to increased performance on exams (Multon, Brown, & Lent, 1991; Pajares, 1996). However, the magnitude of the relations between these psychosocial factors and educational performance would not be as large as the relations between Mastering Biology use and exam scores.

Method

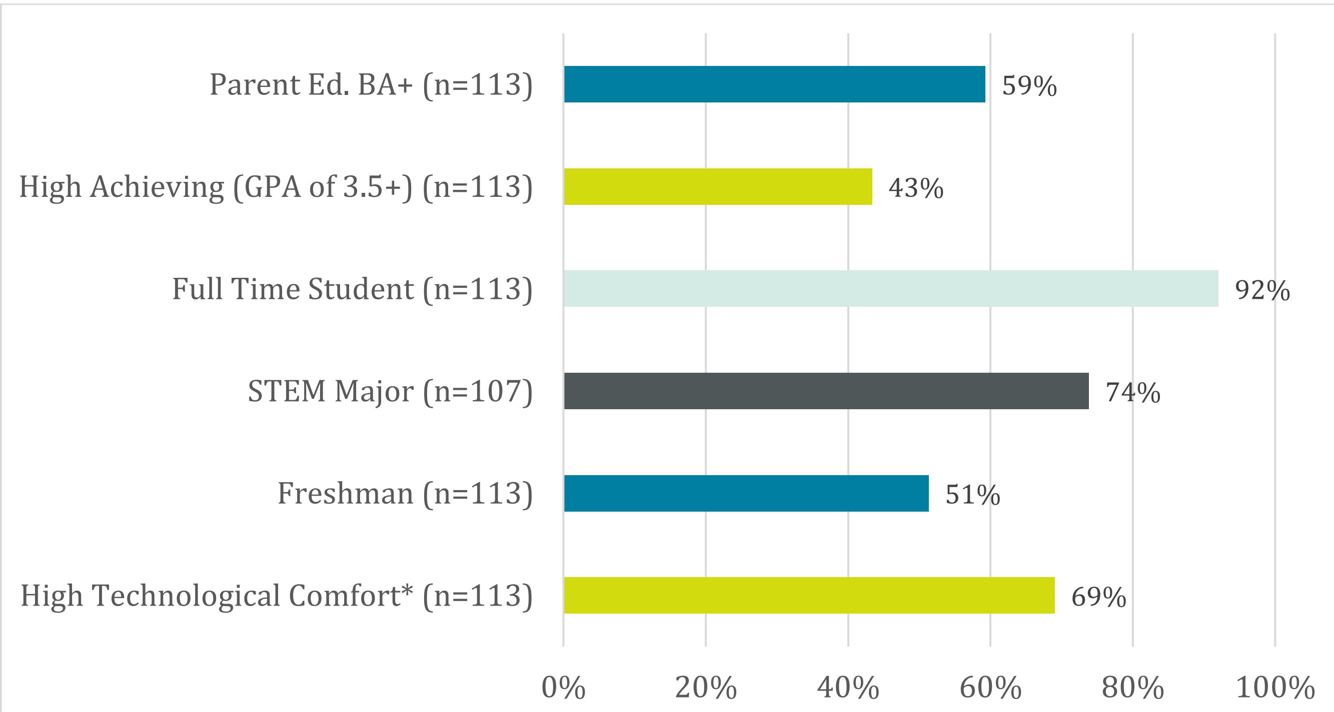
This study examined the association between the use of Mastering Biology and students' achievement in course exams after controlling for confounding student characteristics that might affect achievement, such as socioeconomic status and prior achievement. Mastering Biology was used by the instructor in this study for homework assignments. We measured students' Mastering Biology use through performance in homework assignments, number of assignments for which students asked for hints and the total time spent.

Participants

This study was carried out during the Spring 2017 semester in a foundational biology course focused on Mendelian and population genetics, evolution and ecology, which was taught by a single instructor in a North American, state-related, land-grant doctoral university. The course provides a foundation for subsequent core and advanced courses in the university's Department of Biology. About 230 students were enrolled in the course in Spring 2017, and approximately 150 students consented to participate in the study. Of the students who agreed to take part, none indicated they took the class under the pass/fail option.

About 59% of the students reported that their parents had at least 16 or more years of schooling (i.e., greater than a BA), and about 43% of the students had a grade point average of at least 3.5 before the start of the Spring 2017 term. Figure 2 shows the characteristics of the students enrolled in the course.

Figure 2: Characteristics of students enrolled in the foundational biology course



**Note:* High Technological Comfort refers to being a nine or ten on a ten-point scale when asked about being comfortable with technology.

Data collection

The study used a mixed-methods design, with data collected from the students, instructor, institution and Pearson. Students who agreed to take part were asked to complete a survey in the middle and at end of the semester. The instructor provided data on student performance, such as course grades. The transcript office at the university provided student identifiers (i.e. first name, last name and email) for students who took part. The office also provided de-identified data on student performance on all prior courses along with a key to link the student transcript data with the other sources of data. Platform use data was taken from the Pearson database.

Survey data from the students, course grade data from the instructor, transcript data from the institution and platform use data from Pearson were then merged by Pearson. For details on the sample sizes that resulted from the data merge and the final samples used for the analyses, please see

Appendix A.

Data on student characteristics

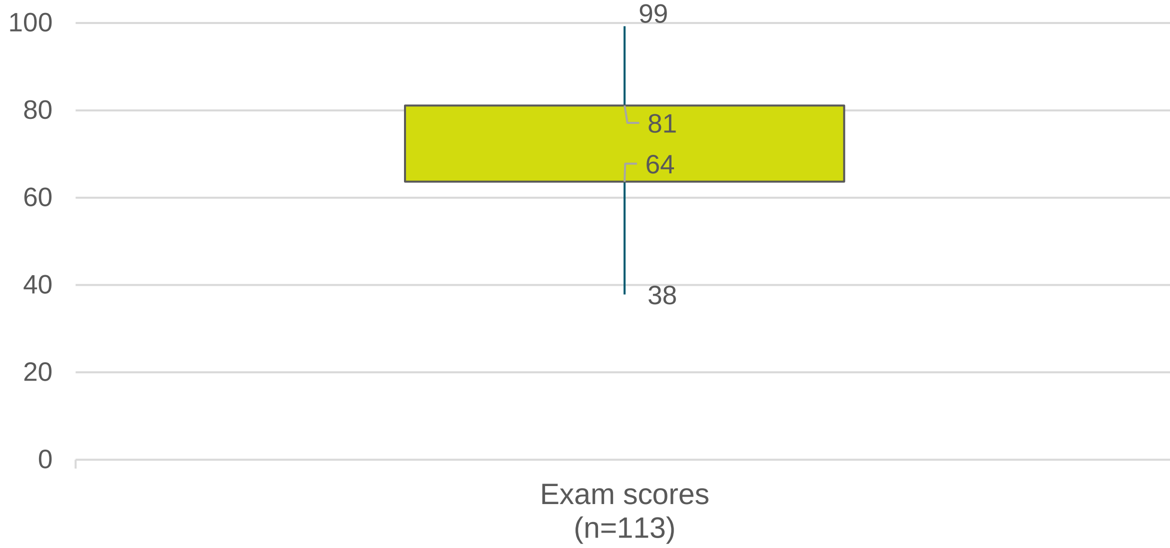
For this study, the survey provided data on the highest level of education attained by either parents (in years), if the student was a full-time student, if the student was a STEM major, if the student was in their first year in college, and if the student was comfortable with technology.

The institution also provided data on student performance in every class taken before Spring 2017, which was used to create a measure of prior achievement. However, only letter grades for each course were provided. These letter grades were converted to numeric grades (A=4.0, B=3.0, C=2.0, D=1.0, and F=0.0) and averaged to obtain the students' prior GPA. Students who had an average greater than 3.5 were considered high-achieving students. It is important to note that only these five letter-grade options were available — finer distinction of the letter-grades (e.g. A-, B+, C-, etc.) was not used at this institution. If a letter-grade was not provided for a class that a student took before Spring 2017 (e.g. class taken as pass/fail, withdrawn, incomplete, etc.), performance in that class was not used to calculate the measure of prior achievement.

Data on exam grades

During the semester, the instructor administered three interim exams and one final exam. The average exam score used as the outcome measure for the current study was weighted based on the weight given to each exam by the instructor. The interim exams were worth 75 points while the final exam was worth 100 points. Further details of the exams (such as exam format and timing) are provided in the course syllabus (see Appendix B). Figure 3 shows the distribution of weighted average exam grades for students on the course. The mean weighted average exam score was 72.32 points with a standard deviation of 11.84.

Figure 3. Weighted average exam scores of students enrolled in the foundational biology course



Mastering Biology platform data

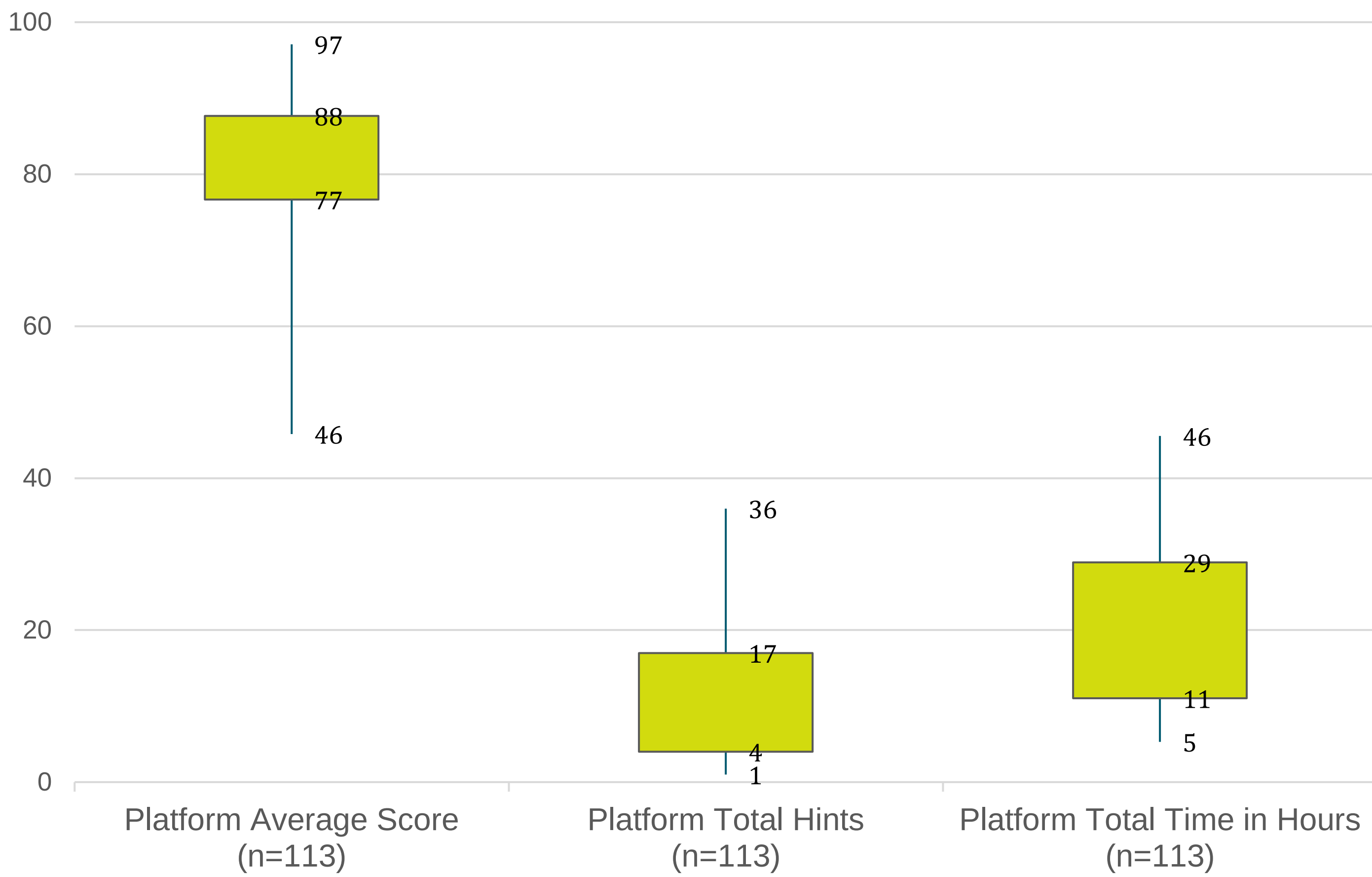
Mastering Biology was used by the instructor throughout the course for homework assignments. Platform data on Mastering Biology provided measures of both student performance on homework assignments as well as students' engagement within Mastering Biology. The level of engagement in Mastering Biology was measured by the number of assignments for which a student requested a hint and the total time spent on the platform. Figure 4 shows the descriptive statistics for Mastering Biology use and the average score for homework assignments. It is important to note that there was no penalty or bonus when requesting hints — students could request them whenever they were needed.

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 was assigned a score of 0, indicating that the student did not complete that assignment. Scores were only given for homework assignments submitted on time. Assignments consisted of a variable number of questions per assignment, and the student could have either three or six attempts to achieve the correct answer (depending on the question). Assignments also included pre-lecture tutorial questions from the Dynamic Study Module that were scored on completion rather than performance. On average, students scored 82.18% (SD = 8.85) on the platform.

'Total hints' is a measure of how many assignment problems students requested hints for. The number of hints is a conservative measure of the number of hints a student requested throughout the semester because students can request multiple hints during a particular assignment. Students were not penalized for requesting additional hints when solving homework questions. On average, students requested hints on 11.85 assignments (SD = 9.71).

‘Total time on platform’ reflects the total time students spent logged into Mastering Biology. On average, students spent about 19.85 hours (SD = 11.02) on the platform throughout the semester. This variable did not differentiate between the time students spent actively engaged in the course content while logged in and when the students were logged in but not engaged. For this reason, results regarding the total time spent in Mastering Biology should be viewed with caution.

Figure 4: Mastering Biology descriptive statistics based on platform data



Psychosocial student characteristics

Test-taking anxiety

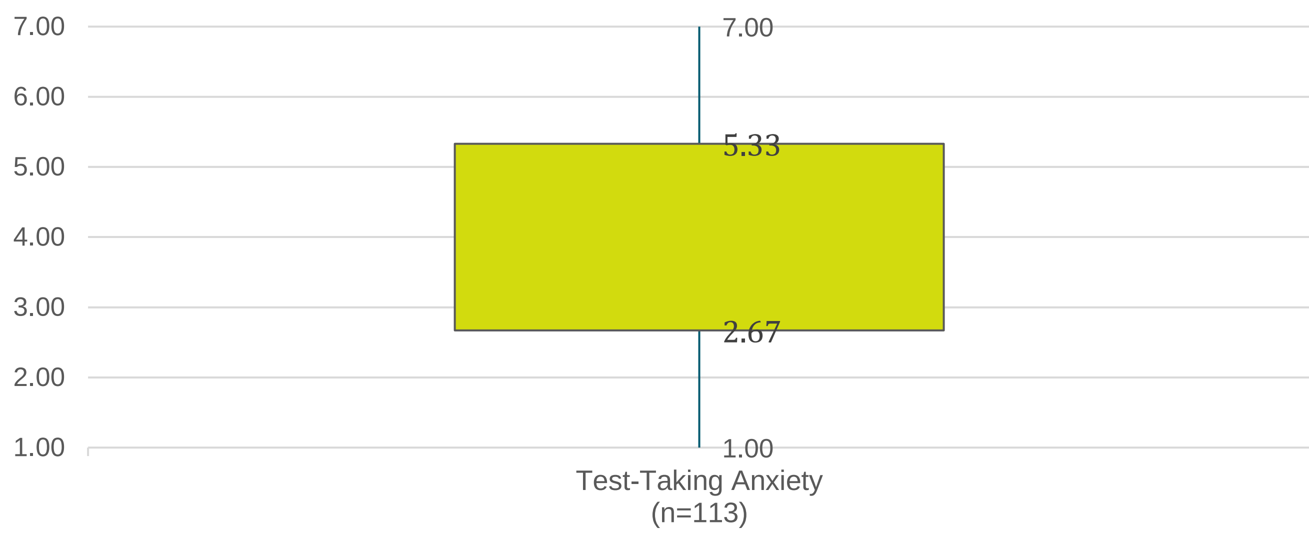
In the student survey administered in the middle of the semester, students reported their test-taking anxiety (three items, α=.90) on a scale from 1 to 7. A sample item is: "I am so nervous during a test that I cannot remember facts I have learned". Higher values indicate higher levels of test-taking anxiety. Mean test-taking anxiety was 4.11 out of 7 with a standard deviation of 1.76.

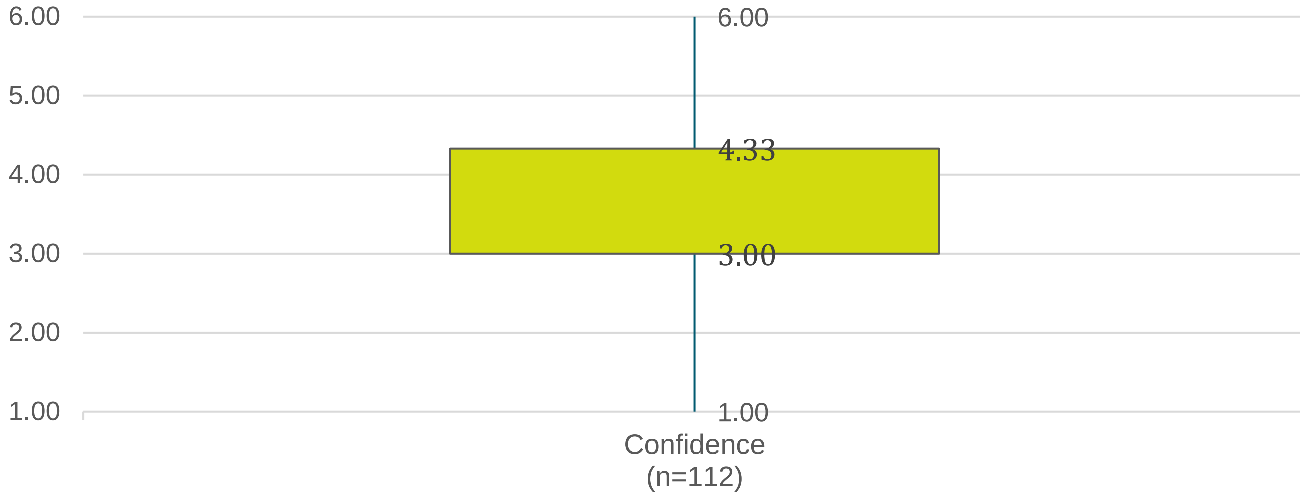
Confidence

Students reported confidence in their knowledge and skills in the current biology course (three items, α=.85) on a scale from 1 to 6, Responses to items were averaged to create a composite measure with higher values indicating higher levels of confidence. An example items is: "Think critically and analytically". Mean confidence was 3.64 out of 6 with a standard deviation of 1.19.

Figure 5 presents the descriptive statistics for each scale. The detailed process for how each scale was created and the full set of items is detailed in Appendix C.

Figure 5: Psychosocial student characteristics



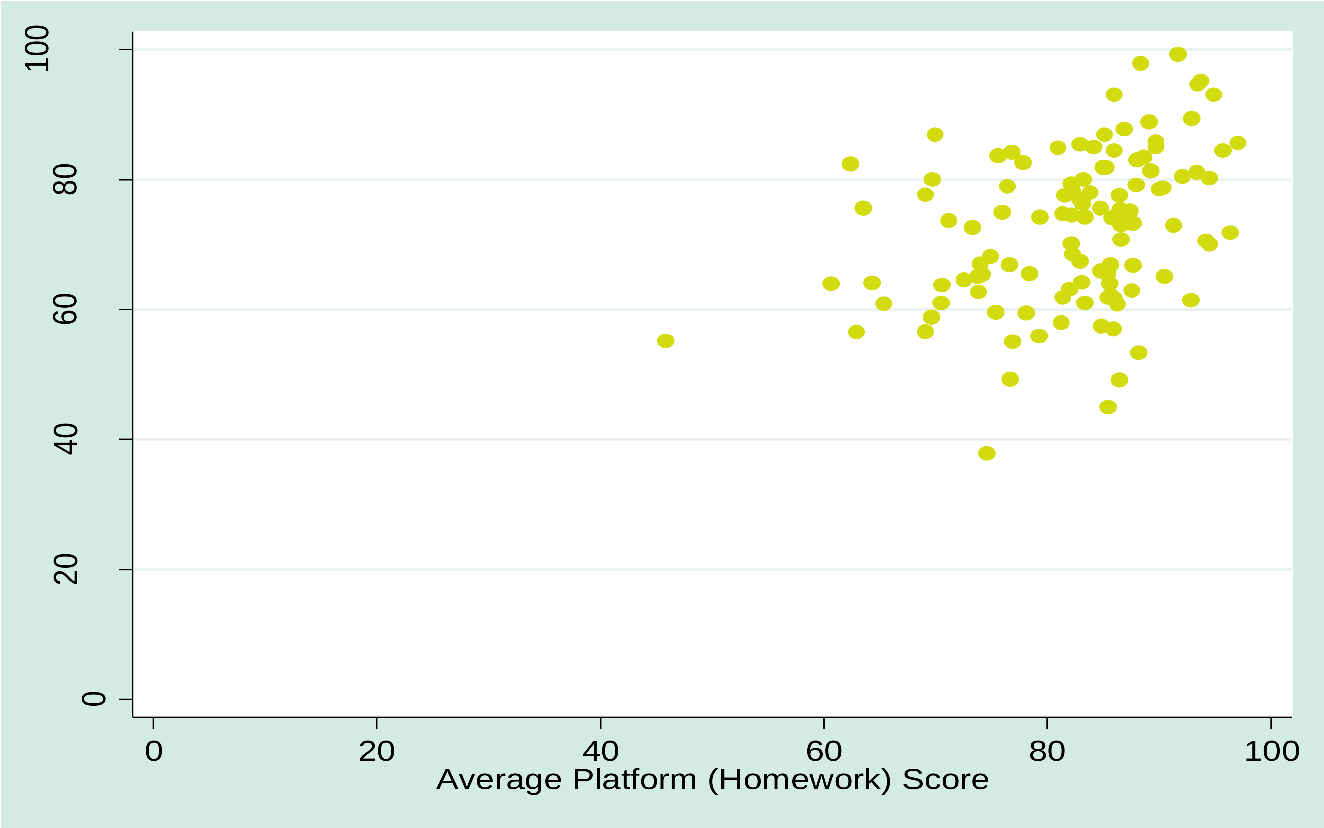


Analysis method

A set of ordinary least squares (OLS) regressions were conducted to assess the relationship between Mastering Biology use and student achievement, as measured by performance in course exams. To better assess the relationship between Mastering Biology and exam scores, two different specifications of performance on Mastering Biology were used. The first model uses a continuous specification of platform score while the second model categorized students based on their platform average scores to explore potential non-linear relations between Mastering Biology and achievement.

A second model explores potential non-linear relations due to the distributions of the Mastering Biology platform score (Figure 4) as well as the scatterplot indicating the relationship between the weighted average exam scores and the average homework (platform) scores (Figure 6). The scatterplot shows that the relationship between exam scores and homework scores can be linear, but it is certainly not clear-cut. In addition, the scatterplot also shows that homework scores were at the higher end of the range (all except one student scored 60% or higher), thereby limiting our ability to find a clear-cut, linear relationship.

Figure 6: Scatterplot of the relationship of the exam scores to the average homework (platform) scores



To account for student factors that could influence this relationship, student demographic information and psychosocial characteristics were included in the regression models.

Results

Mastering Biology platform use and average exam scores

Table 1 shows the results from the OLS regressions that examine the relationship between Mastering Biology platform use and exam scores (for the standardized coefficients, please refer to Appendix D). The table also shows the relationship between the baseline student characteristics (including student psychosocial characteristics) and exam scores 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 Biology are significantly associated with achievement in the course exams. In the analysis, students' baseline characteristics were included in the model to take into account prior differences. The average Mastering Biology score and average exam score were measured in percentage points. Column 1 explores a linear relationship between average Mastering Biology platform score and exam scores. However, given that Figure 6 seems to indicate that it is not a clear-cut, linear relationship, Column 2 further explores the possibility of a non-linear relationship.

Table 1: OLS results with the average exam scores as the outcome measure

		(1)	(2)
Platform Variables			
Average score		0.299^{+}	
		(0.161)	
Average score			
(<70% = baseline category)			
	70-79%		-2.688
			(3.117)
	80-89%		1.163
			(3.003)
	90-100%		9.397^{*}
			(4.022)
Total time		-0.096	-0.115
		(0.110)	(0.106)
Hints		0.141	0.159
		(0.117)	(0.116)
Student Characteristics			
Highest level of education by either parents		0.373	0.413

(years)	(0.481)	(0.494)
High-achieving student (prior GPA of 3.5+)	5.244*	5.239*
	(2.407)	(2.183)
Is a full-time student	11.719**	10.922**
	(4.407)	(3.926)
Is a STEM major	-3.057	-3.773+
	(2.088)	(2.034)
Is a freshman	1.237	1.382
	(1.871)	(1.830)
Has High Technological Comfort (9 or 10 out of	-1.487	-1.892
10)	(1.991)	(1.835)
Latent Constructs (Standardized)		
Test-taking anxiety	-3.714**	-3.920**
	(1.384)	(1.272)
Confidence	1.295	1.040
	(1.333)	(1.267)
Constant	31.893+	56.114***
	(16.739)	(8.351)
R^2	0.464	0.517
Observations	106	106

Note. Standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Column 1 of Table 1 found certain student characteristics were related to exam performance. Specifically, being a student with a prior GPA of at least 3.5 before Spring 2017 and being a full-time student were both significantly related to higher average exam scores. Additionally, high levels of test-taking anxiety was related to a decrease in academic performance. A standard deviation increase in test-taking anxiety is related to a 3.71% decrease in exam scores.

Considering the main goal of the study around Mastering Biology platform use, there are no significant relations between platform use and average exam scores. The relationship between the average platform score on Mastering Biology and exam scores was also not significant, though it is approaching significance (*p*=.066). This could possibly be due to a non-linear relationship between the Mastering Biology platform scores and exam scores. Figure 6 seems to indicate the linear relationship is not clear-cut.

Figure 4 also shows a highly skewed distribution of average scores for Mastering Biology. The average score was 82% with the middle 50% of students scoring between 77% and 88%. This high average can perhaps be attributed to how Mastering Biology was implemented by the instructor. The instructor did not penalize students for asking for hints and allowed students three or six chances (depending on the question) to correctly answer questions on the Mastering Biology homework. Having multiple chances could be part of the effort to encourage the students to practice. Furthermore, the instructor assigned many pre-lecture tutorial questions from the Dynamic Study Module that were scored based on completion rather than performance. Because students were afforded multiple chances to correctly solve their homework questions, it is possible that students could score highly on the homework without learning the course materials. Hence, the relationship between average Mastering Biology scores and exam scores might not be clear-cut and linear.

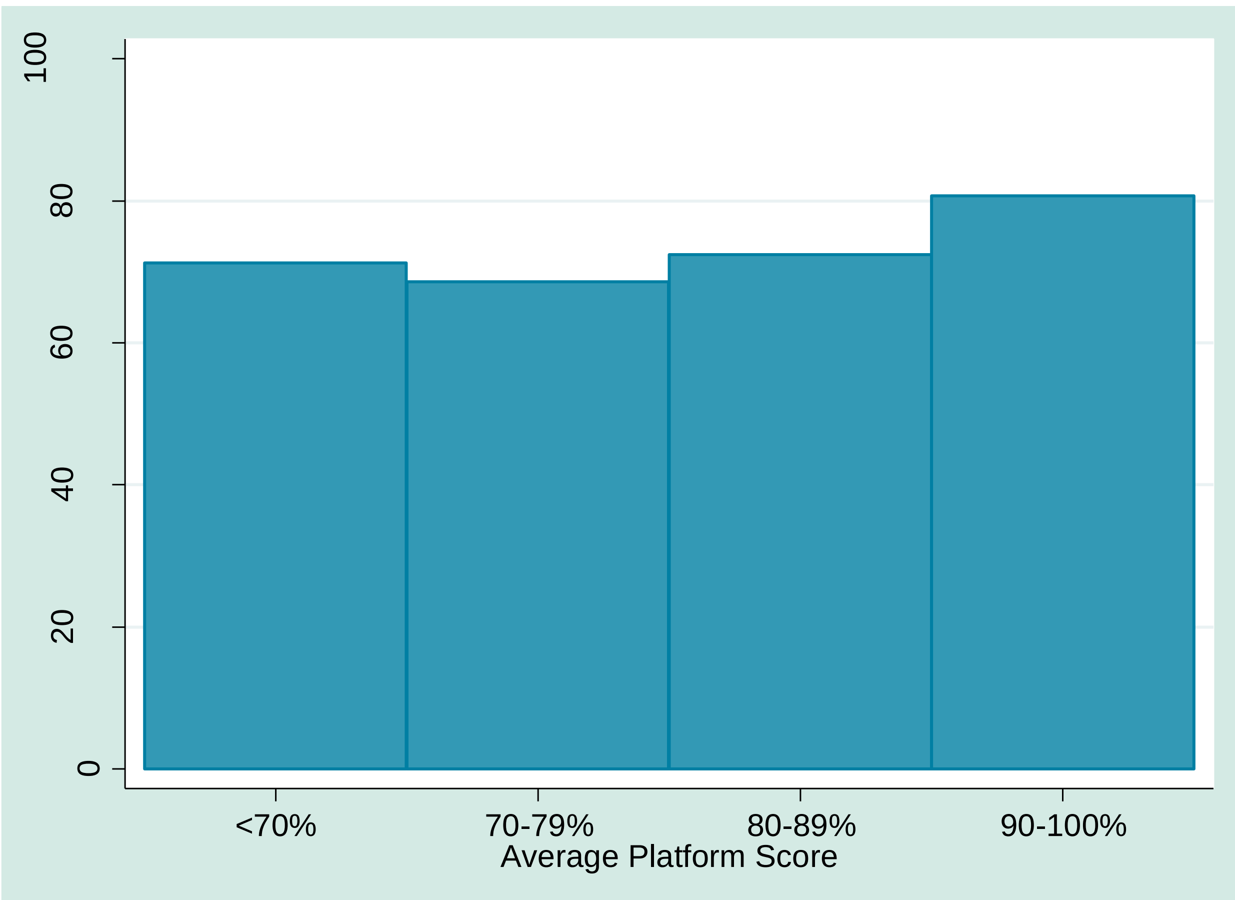
Our suspicion of a non-linear relationship between Mastering Biology platform scores and exam scores is further investigated. Column 2 of Table 1 examines a regression model similar to that in Column 1 but, instead of exploring a linear relation between average Mastering Biology platform scores, it explores a potential non-linear relation. Students are grouped into different categories based on their average platform score, with students scoring less than 70% serving as the reference group for comparison (i.e. students scoring from 70 to 79% are compared to the less-than-70% group, students scoring from 80 to 89% are compared to the less-than-70% group, etc).

Similar to the results in Column 1, being a student with a prior GPA of at least 3.5 before Spring 2017 as well as being a full-time student were both significantly related to higher average exam scores. Higher levels of test-taking anxiety was related to a decrease in academic performance. A standard deviation increase in test-taking anxiety is related to a 3.92% decrease in exam scores. When considering the relations between Mastering Biology platform use and exam scores, there were no significant relations between total time and hints on average exam score.

However, when examining the relations between scores on Mastering Biology and exam scores, there is evidence of a significant non-linear relationship. Students who scored at least 90% or more on the platform were associated with a 9.4% increase in exam scores compared to students who scored less than 70% on the platform. Interestingly, students who scored between 70 and79% or 80 and 89% on the Mastering Biology platform did not significantly outperform students who scored less than 70% on the platform. Results suggest that students need to score above a certain threshold for Mastering Biology to be significantly associated with exam scores.

A Wald test for the joint significance of the four categories shows that they are not equal to each other (p=.005) and are not equal to zero (p=.013). Additional analysis was conducted where the reference category from the model in Column 2 of Table 1 (less than 70% on the platform) was switched to between 70 and 79% (Appendix Table E1), 80 and 89% (Appendix Table E2) and 90% or more (Appendix Table E3). The results indicate that there are no significant differences between the less-than-70% group, the 70-79% group and the 80-89% groups — only the 90% or more group is associated with higher average exam scores. Figure 7 presents a visual representation of the relationship between average platform score and *expected* average exam scores based on students' performance on Mastering Biology.

Figure 7: OLS results with average exam scores as the outcome measure



Implications for claims about platform variables and outcomes

Based on the OLS results in Table 1, the following claim about platform variables and achievement can be made:

- Averaging at least 90% or better on Mastering Biology homework assignments is associated with a 9% increase in exam scores.

Discussion

The main goal of this study is to determine the relationship between student use of Mastering Biology and achievement in a foundational biology course at a North American, state-related, land-grant doctoral university. To support the validity of the relationship, the study accounts, and statistically controls, for many important student factors that can influence the relationship between Mastering Biology use and achievement, such as socioeconomic status and prior achievement. The study also accounts for certain student psychosocial characteristics, such as test-taking anxiety and confidence in a course that might potentially have an impact on achievement.

The study finds that certain student factors were related to exam scores. Specifically, being a high achieving student as well as being a full-time student were both significantly related to higher average exam scores. Higher test-taking anxiety was related to a decrease in academic performance.

Taking into account these important student factors, the study hypothesized that higher engagement in Mastering Biology, as measured by increased performance, time and hints requested, would have a significant positive relation with academic performance. For example, an increased use of hints could potentially help students revisit the fundamental steps required to think critically before solving a problem. Similarly, if students were mastering the course content as reflected in their performance on the Mastering Biology homework assignments, it is hypothesized that they could also perform just as well in the exams.

The results did not fully support the hypotheses. No significant relationships were found between hints and time spent in Mastering Biology and exam scores. The relationship between the average score on Mastering Biology homework assignments with exam scores was found to be non-linear. Specifically, we found that the average score in Mastering Biology was positively and significantly associated with average exam scores *only if* a student scored at least 90%. This non-linear relationship can perhaps be attributed to how the instructor implemented Mastering Biology in her course. Students were allowed multiple hints and multiple attempts on the homework assignments and were given credit for completing pre-lecture tutorial questions in the Dynamic Study Module. This may account for the high average scores on Mastering Biology homework, as well as the fact that only very high homework performance (i.e. in the 90% or more range) was associated with higher exam scores. The implication is that, through multiple attempts and availability of hints, students may have been able to earn relatively high homework scores without necessarily mastering the course content, and perhaps it was only the highest performers who ultimately mastered the content. Future research should examine this hypothesis.

We also found that total time spent on the platform and the number of hints accessed by a learner were not significantly related to exam scores. One limitation of the measure of time spent used in this study is that it cannot distinguish between active time spent engaged in the course materials versus idle time spent simply logged into Mastering Biology, which could explain the null finding. In addition, it may be that spending more time on homework and requesting more hints, by themselves, are not enough to ensure mastery of the course material. Struggling learners who are conscientious may spend more time and request more hints than learners with a good grasp of the material. But low-performing learners who are not conscientious may not be motivated enough to spend extra time and open hints. This is another area for future research.

Limitations

This study has a number of limitations. First, the research design only allows us to make correlational claims and not causal claims about Mastering Biology and achievement. We, therefore, cannot know whether higher achievement in Mastering Biology homework assignments would actually lead students to improve their achievement in their course exams or whether another factor is at play. Because we could not account for all possible confounding factors, we are not able to rule out the influence of these 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 such as student race and gender. Lastly, the study had a small sample size using data from only one biology course in a single semester at one university with the instructor implementing Mastering Biology tailored to her course. This limits the potential generalizability of the findings for different settings.

Implications of findings for product implementation and further research

The findings from this study are a step towards understanding how the use of Mastering Biology is associated with student achievement. One direction for future research suggested by the findings is to examine whether other types of interactions could affect student achievement. In this study, we only examined the number of hints and time spent in Mastering Biology, alongside the student's average score across all the homework assignments given by the instructor in the course. A problem with the time spent data is that we cannot differentiate between the time when students were actively engaged and when they were logged in but not engaged. There may be other types of interaction in Mastering Biology that could be a more accurate measure of students' level of engagement, such as the number of solution checks requested by students while completing homework assignments. This data was, unfortunately, not available for this study.

Further studies on Mastering Biology 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 to increase generalizability and better understand the significant and non-significant relations in the models. Finally, they could control for a wider and more robust array of student variables to more thoroughly adjust for confounding factors that might also influence achievement.

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Appendix A. Data merge process and resulting analytic sample

Data file	Initial *N*	Data cleaning step	*N* lost or added	Cleaned *N*
Data sources				
Platform data	242	No Issues	0	242
Gradebook data	228	No Issues	0	228
Transcript	114	No Issues	0	114
Consent	152	No Issues	0	152
Survey data	121	No Issues	0	121
Initial cleaning				
Clean survey data	121	Drop cases where students answered survey twice	4	117
Clean consent data	152	No Issues	0	152
Clean platform data	242	No Issues	0	242
Clean gradebook data	228	No Issues	0	228
Merge data				
Start with platform data ***(as base dataset)***	242	Drop cases without name identifiers or platform data	3	239
Merge consent to platform data ***(merged dataset now called master dataset)***	239	Drop cases that do not provide consent 149 matched cases 93 unmatched cases 90 from Platform 3 from Consent 4 from Survey	90	149
Merge survey to master data	149	Merge and then drop unmatched cases 113 matched cases 36 unmatched cases 36 from Platform 4 from Survey	36	113
Merge gradebook data to master data	113	Merge and then drop unmatched cases 113 matched cases 115 unmatched cases 115 from Gradebook	0	113

Merge transcript data to master data	113	Merge and then drop unmatched cases 113 matched cases 1 unmatched case 1 from Transcript	0	113
Exclusion criteria for analysis				
Drop cases with missing data on student characteristics	113	6 cases missing data on if student was a STEM major 1 case missing data on Confidence scale	7	106

Appendix B. Course syllabus

Instructor and institutional identifiers have been removed for confidentiality.

[redacted] Organismal Biology [redacted]

Course description: This course provides science majors with a foundation in organismal biology: Mendelian and population genetics, evolution, and ecology. Topics include patterns of inheritance, genetics, evolution, speciation, phylogeny, and behavioral, population, community and ecosystem ecology.

Academic Semester: Spring 2017

Instructor:	[redacted]
Office number:	[redacted]
Contact Information:	[redacted]
Class time:	M W 12:30-1:50 PM
Office hours:	M W 10:30-12:00; Other times by appointment

This course provides students a foundation for subsequent core and advanced courses offered by the [redacted] Department of Biology. (1) Students should learn and understand basic biological concepts and be able to apply these concepts in novel situations. (2) This course will provide students with opportunities to experience science as an investigative process. (3) Students are responsible for understanding and being able to answer questions pertaining to all information presented in lecture and assigned readings.

General Education Core Objectives/Learning Outcomes

Life & Physical Sciences Component Outcomes

- Students will describe, explain, and predict natural phenomena using the scientific method.
- Students will describe interactions among natural phenomena and the implications of scientific principles on the physical world and on human experiences.

General Education Core Objectives/Competencies Outcomes:

- **Teamwork**
  - Students will demonstrate the ability to consider different points of view and to work effectively with others to support a shared purpose or goal.
- **Communication**
  - Students will demonstrate effective development, interpretation and expression of ideas through written, oral and visual communication.
- **Critical thinking**
  - Students will demonstrate creative thinking, innovation, inquiry, and analysis, evaluation and synthesis of information.
- **Empirical and Quantitative Skills**
  - Students will manipulate and analyze numerical data or observable facts resulting in informed conclusions.

Additional departmental / instructor course outcomes:

Students will generally (in addition to specific outcomes identified for each lecture):

1. Develop an understanding of the basic mechanisms that lead to evolution and how living organisms adapt to their surroundings.
2. Develop an understanding of speciation and phylogenetic relationships among living organisms.

1

3. Develop an understanding of the complex interactions between and within individuals, populations, and communities.
4. Develop an understanding of the contributions that all organisms make towards the sustainability of life on the earth.

Course Materials:

1. THE TEXT (**REQUIRED**): *Biological Science*, by Freeman et al. 2016 (6th edn., Pearson), **OR** the E-book version of *Biological Science*, by Freeman et al. 2016.
2. MASTERING BIOLOGY (**REQUIRED)** (see last page for registration assistance)

Special Needs: Students with special needs (as documented by the Office of Disability Services: [redacted] should identify themselves at the beginning of the semester.

Lecture Attendance Policy: Attendance at all lectures is expected and will be essential for successful completion of the course. It should be understood that you are responsible for all material covered in class. Lectures in [redacted] stand on their own and the assigned textbook readings support the lecture (not vice-versa). I will provide a hardcopy of each lecture outline in class. If you miss class, you will need to come to my office to get a copy of the outline, or copy from a classmate. They will not be posted online.

Breakdown of Grading:

Exam 1	75 points
Exam 2	75 points
Exam 3	75 points
Final Exam	100 points
Mastering Biology	100 points
In class activities + Learning Catalytics	75 points

Final Course Grade Standards: The following grade standards will be strictly applied. NO EXTRA CREDIT WILL BE GIVEN. PLEASE DO NOT ASK.

90-100 % = A	(≥450-500 points)
80-89.9 % = B	(≥400-<449 points)
70-79.9 % = C	(≥350-<399 points)
60-69.9 % = D	(≥300-<349 points)
0-59.9 % = F	(<300 points)

Exams and grading: Exams may be a combination of multiple choice, fill in the blank, and short answer questions. A total of five exams will be given during the semester, including the final exam. Each exam will focus on conceptual issues and will require the application of analytical skills (expect questions that require problem solving). Each exam will be comprehensive (i.e., knowledge of concepts learned throughout the semester will be assumed on each exam). To the benefit of all students, all exam scores are graded *relative to the highest student's score. This grading scale represents a significant curve as it assigns scores based on comparison to the performance of other students in the class. This manner of grading allows students in the class to set the standards for excellence in the course. I know of no fairer policy.* To be perfectly clear here is an example so that all of us understand this beneficial grading procedure: if the highest grade on an exam is 70/75, your grade would be your score on the exam divided by 70 and multiplied by 75.

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Make-up Policy: **You will not be able to make-up an exam** unless you notify me well in ***advance*** and can provide DOCUMENTATION deemed acceptable. Request for make-ups will be granted only in extraordinary circumstances. Make up exams will consist of an essay exam administered by, and at a time selected by, the instructor of record.

You must query any grading discrepancies VIA EMAIL by the class period after I post grades. This means that if I post the exam scores on Wednesday, you must e-mail me about grading issues by the next Monday.

MASTERING BIOLOGY: MasteringBiology assignments will be available on my MasteringBiology course site. **There will be NO make up assignments or extensions**.

Learning Catalytics: Unannounced in class activities administered via Learning Catalytics and/or TRACS will also be given at the discretion of the instructor. Learning Catalytics comes with your MasteringBiology subscription if you purchased the e-book. If you purchased MasteringBiology without ebook, you will also need to sign up separately for Learning Catalytics through the publisher's website. **There will be NO make ups for missed points from Learning Catalytics.**

Academic honesty: I expect students to behave with integrity. Students found cheating on quizzes or exams will receive a score of zero for that exam and will be subject to disciplinary action as specified in University code [redacted] **Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failing the course and dismissal from the University.**

[redacted] Honor Code

As members of a community dedicated to learning, inquiry, and creation, the students, faculty, and administration of our university live by the principles in this Honor Code. These principles require all members of this community to be conscientious, respectful, and honest.

WE ARE CONSCIENTIOUS. We complete our work on time and make every effort to do it right. We come to class and meetings prepared and are willing to demonstrate it. We hold ourselves to doing what is required, embrace rigor, and shun mediocrity, special requests, and excuses.

WE ARE RESPECTFUL. We act civilly toward one another and we cooperate with each other. We will strive to create an environment in which people respect and listen to one another, speaking when appropriate, and permitting other people to participate and express their views.

WE ARE HONEST. We do our own work and are honest with one another in all matters. We understand how various acts of dishonesty, like plagiarizing, falsifying data, and giving or receiving assistance to which one is not entitled, conflict as much with academic achievement as with the values of honesty and integrity.

THE PLEDGE FOR STUDENTS
Students at our university recognize that, to insure honest conduct, more is needed than an expectation of academic honesty, and we therefore adopt the practice of affixing the following pledge of honesty to the work we submit for evaluation:

I pledge to uphold the principles of honesty and responsibility at our university.

Classroom Courtesy:

- Do not talk in class when I am talking to the whole class or when we are watching a video presentation as a class—it's rude because it disturbs and distracts other students.
- PLEASE turn the ringer OFF on all cell phones. You may use phones, tablets etc. for engaging in classroom related matters only.
- PLEASE don't come late or leave early (If you must leave early for a valid reason, you must identify yourself at the beginning of class, and exit only from the rear doors).

Email Policy: You should only use email to set up a one-on-one meeting with me if office hours conflict with your schedule. Use the subject line "Meeting request." Your message should include at least two times when you would like to meet and a brief (one-two sentence) description of the reason for the meeting. For more in-depth discussions (such as guidance on assignments or clarification of lecture material) please plan to meet in person, and not right after or before class. Our conversations should take place in person rather than via email, thus allowing us to get to know each other better and fostering a more collegial learning atmosphere. Email communications must: (a) include a proper salutation (i.e., [redacted]; (b) come from your [redacted] email address; (c) be composed using complete sentences with proper grammar and spelling; and (d) be signed with your full name. If these requirements are met, I usually respond within 24 hours.

Please note this important date: March 28th. This is the last day to drop a class. If you drop on or before that date you will receive a grade of "W." After this date you cannot drop the course. This is University Policy, and I have no authority to allow exceptions.

Supplemental Instruction

Supplemental Instruction (SI) is a nontraditional form of tutoring provided by [redacted] and the Department of Biology that focuses on collaboration, group study, and interaction for assisting students in undertaking "traditionally difficult" courses. SI targets courses with a minimum 30% rate of students that drop, withdraw, or fail, and then provides a trained peer who has successfully negotiated the course to assist its future students. This peer, called the SI Leader, attends a section of the course, participates as any normal student (takes notes, exams, etc.), and then facilitates 3 one-hour study sessions per week for group study. SI Leaders are trained to help students improve their study skills and model the types of behaviors that make students successful. The hope is that students that attend session will be better prepared for other difficult courses they will encounter, and on average, students participating regularly in SI sessions score one-half to one whole letter grade better than students choose not to participate. For more in-depth information regarding Supplemental Instruction, including an up to date session schedule, please visit [redacted] If you have concerns regarding the SI program, please contact [redacted] or [redacted] Please understand that ***SI Leaders do not have administrative authority*** in this class and that attending session is not in any way a substitute for attending lecture! Specific questions regarding grades or grading standards should be directed to your Professor or Instructional Assistant (IA).

Tentative Schedule of Lectures and Exams

These are readings from the textbook. You will occasionally be assigned external reading assignments for some topics. I will assume that you have read the assignments prior to class attendance.

Day	Date	Lecture	TOPIC	Reading Assignment
Weds	Jan 18	1	Introduction to course	CH 1.3, 1.5-1.6 BioSkills 2, 3, 12, 18
Mon	Jan 23	2	Meiosis	CH 13.1, 13.2, 13.4
Weds	Jan 25	3	Mendelian Genetics	CH 14.1-14.2
Mon	Jan 30	4	More Mendelian Genetics	CH 14.3-14.5
Weds	Feb 1	5	Genes, Development and Evolution	CH 21
Mon	Feb 6	6	History of Evolutionary Thought	CH 22.1
Weds	Feb 8	7	Evidence of Evolution	CH 22.2
Mon	Feb 13	8	Natural Selection	CH 22.3-22.5 Bioskills 17
Weds	**Feb 15**		**Exam 1: Covers L1-L8**	
Mon	Feb 20	9	Hardy-Weinberg Equilibrium	CH 23.1 Bioskills 4
Weds	Feb 22	10	Microevolution	CH 23.2-23.6
Mon	Feb 27	11	Speciation	CH 24
Weds	Mar 1	12	Phylogenetics	CH 25.1 Bioskills 13
Mon	Mar 6	13	Diversity: Prokaryotes & Protists	CH 26.3, 27.3
Weds	Mar 8	14	Diversity: Land Plants	CH 28.3
Mon	**Mar 13**		**No Class: Spring Break**	
Weds	**Mar 15**		**No Class: Spring Break**	
Mon	Mar 20	15	Diversity: Animals I	CH 30.1-30.3
Weds	Mar 22	16	Diversity: Animals II	CH 32.1-32.4, CH 25.3
Mon	Mar 27	17	Diversity: Human Evolution	CH 32.5
Weds	Mar 29		**Exam 2: Covers L9-L17**	
Mon	Apr 3	18	Behavioral Ecology	CH 49.1, 50.1-50.2, 50.4
Weds	Apr 5	19	Behavioral Ecology	CH 50.5-50.6
Mon	Apr 10	20	Sexual Selection	CH 50.3, CH 23.3
Weds	Apr 12	21	Life History Evolution	CH 51.2
Mon	Apr 17	22	Population Ecology	CH 51.3-51.4
Weds	Apr 19	23	Community Ecology	CH 52.1-52.2
Mon	Apr 24	24	Community Ecology	CH 52.3-52.4
Weds	Apr 26	25	Biodiversity and Conservation Biology	CH 53.3, CH 54
Mon	**May 1**		**Exam 3: Covers L18-25**	
Weds	**May 10**		**Final Exam: Comprehensive 11-1:30**	

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Appendix C. Psychosocial factors

Test-taking anxiety

The test-taking anxiety questions came from the Test Anxiety component of the Motivated Strategies for Learning Questionnaire (Pintrich & De Groot, 1990). Students indicated how accurate the following three statements regarding their test-taking anxiety were on a scale from 1 to 7, where higher values indicate higher levels of anxiety (1 = Not at all true of me; 7 = Very true of me). Responses to items were averaged to create a composite measure with higher values indicating higher levels of test-taking anxiety. The items were considered highly reliable (α=.8956).

I am so nervous during a test that I cannot remember facts I have learned
I have an uneasy, upset feeling when I take a test
When I take a test, I think about how poorly I'm doing

Confidence

In the same survey, students indicated how accurate the following three statements regarding their confidence in the current biology course were on a scale from 1 to 6, where higher values indicate higher levels of confidence (1 = Not confident at all; 6= Very confident). Responses to items were averaged to create a composite measure with higher values indicating higher levels of confidence. The items were considered highly reliable (α=.8472).

1. Write clearly and effectively
2. Speak clearly and effectively during class
3. Think critically and analytically

Appendix D. Standardized coefficients

Table D1: OLS standardized results with the average exam scores as the outcome measure

	(1)	(2)
Platform variables		
Average score *(standardized)*	0.223+	
	(0.120)	
Average score		
(<70% = baseline category)		
70-79%		-0.227
		(0.263)
80-89%		0.098
		(0.254)
90-100%		0.794*
		(0.340)
Total time *(standardized)*	0.116	0.130
	(0.096)	(0.095)
Hints *(standardized)*	-0.089	-0.107
	(0.103)	(0.099)
Student characteristics		
Highest level of education by either parents	0.087	0.096
(standardized)	(0.112)	(0.115)
High-achieving student (prior GPA of 3.5+)	0.443*	0.442*
	(0.203)	(0.184)
Is a full-time student	0.990**	0.923**
	(0.372)	(0.332)
Is a STEM major	-0.258	-0.319+
	(0.176)	(0.172)
Is a freshman	0.105	0.117
	(0.158)	(0.155)
Has high technological comfort (9 or 10 out of	-0.126	-0.160
10)	(0.168)	(0.155)
Latent constructs (standardized)		
Test-taking anxiety	-0.314**	-0.331**
	(0.117)	(0.107)
Confidence	0.109	0.088

	(0.113)	(0.107)
Constant	-0.881*	-0.873*
	(0.399)	(0.429)
R^2	0.464	0.517
Observations	106	106

Note. Robust standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix E. Table 1 with different reference categories

Table E1: Table 1 with different reference category for Column 2 (average platform score 70-79% as reference category)

	(1)	(2)
Platform variables		
Average score	0.299^{+}	
	(0.161)	
Average score		
<70%		2.688
		(3.117)
70-79% (reference category)		--
80-89%		3.852
		(2.874)
90-100%		12.086**
		(3.856)
Total time	-0.096	-0.115
	(0.110)	(0.106)
Hints	0.141	0.159
	(0.117)	(0.116)
Student characteristics		
Highest level of education by either parents	0.373	0.413
(years)	(0.481)	(0.494)
High-achieving student (Prior GPA of 3.5+)	5.244*	5.239*
	(2.407)	(2.183)
Is a full-time student	11.719**	10.922**
	(4.407)	(3.926)
Is a STEM major	-3.057	-3.773^{+}
	(2.088)	(2.034)
Is a freshman	1.237	1.382
	(1.871)	(1.830)
Has high technological comfort (9 or 10 out of	-1.487	-1.892

10)	(1.991)	(1.835)
Latent constructs (standardized)		
Test-taking anxiety	-3.714**	-3.920**
	(1.384)	(1.272)
Confidence	1.295	1.040
	(1.333)	(1.267)
Constant	31.893+	53.425***
	(16.739)	(9.097)
R^2	0.464	0.517
Observations	106	106

Note. Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E2: Table 1 with different reference category for Column 2 (average platform score 80-89% as reference category)

	(1)	(2)
Platform variables		
Average score	0.299^{+}	
	(0.161)	
Average score		
<70%		-1.163
		(3.003)
70-79%		-3.852
		(2.874)
80-89% (reference category)		--
90-100%		8.234**
		(2.754)
Total time	-0.096	-0.115
	(0.110)	(0.106)
Hints	0.141	0.159
	(0.117)	(0.116)
Student characteristics		
Highest level of education by either parents (years)	0.373	0.413
	(0.481)	(0.494)
High-achieving student (prior GPA of 3.5+)	5.244*	5.239*
	(2.407)	(2.183)
Is a full-time student	11.719**	10.922**
	(4.407)	(3.926)
Is a STEM major	-3.057	-3.773^{+}
	(2.088)	(2.034)
Is a freshman	1.237	1.382
	(1.871)	(1.830)
Has High Technological Comfort (9 or 10 out of 10)	-1.487	-1.892
	(1.991)	(1.835)
Latent constructs (Standardized)		
Test-taking anxiety	-3.714**	-3.920**
	(1.384)	(1.272)
Confidence	1.295	1.040

	(1.333)	(1.267)
Constant	31.893^{+}	57.277***
	(16.739)	(7.357)
R^2	0.464	0.517
Observations	106	106

Note. Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E3: Table 1 with different reference category for Column 2 (average platform score 90-100% as reference category)

	(1)	(2)
Platform variables		
Average score	0.299^{+}	
	(0.161)	
Average score		
<70%		-9.397*
		(4.022)
70-79%		-12.086**
		(3.856)
80-89%		-8.234**
		(2.754)
90-100% (reference category)		--
Total time	-0.096	-0.115
	(0.110)	(0.106)
Hints	0.141	0.159
	(0.117)	(0.116)
Student characteristics		
Highest level of education by either parents (years)	0.373	0.413
	(0.481)	(0.494)
High-achieving student (prior GPA of 3.5+)	5.244*	5.239*
	(2.407)	(2.183)
Is a full-time student	11.719**	10.922**
	(4.407)	(3.926)
Is a STEM major	-3.057	-3.773^{+}
	(2.088)	(2.034)
Is a freshman	1.237	1.382
	(1.871)	(1.830)
Has high technological comfort (9 or 10 out of 10)	-1.487	-1.892
	(1.991)	(1.835)
Latent constructs (standardized)		
Test-taking anxiety	-3.714**	-3.920**
	(1.384)	(1.272)
Confidence	1.295	1.040

	(1.333)	(1.267)
Constant	31.893^{+}	65.511***
	(16.739)	(7.913)
R^2	0.464	0.517
Observations	106	106

Note. Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$