Efficacy and Attitudes Towards Online Homework Systems in First-Semester Calculus*

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Abstract: *In this study, the author compares the academic performance and attitudes of two groups of first-semester calculus students at a small, private university. A control group completed traditional paper-and-pencil homework, while an experimental group completed homework using an online system. Results show an improvement in performance on quizzes and final exams of the experimental group. Furthermore, student survey responses indicate higher satisfaction with the online system.* ***Keywords:*** *online homework, student attitudes, calculus*

1 Introduction

Using web-based homework in mathematics courses is commonplace at colleges and universities across the United States. According to the Mathematical Association of America (MAA), 36% of calculus faculty required students to submit homework via an online system in 2015 (Bressoud, Mesa, & Rasmussen, 2015). Web-based homework also promises students benefits, such as instant feedback and example solutions. Automated grading is popular with instructors due to its time-saving features, providing faculty more time to focus on course preparation, curriculum development, or innovative classroom instruction. Online systems also provide instructors with intelligent formative assessment tools. They identify difficult topics for students, track the time per lesson, and record the number of attempts per problem.

Although research suggests that online homework may yield significant improvements in several aspects, questions remain about the educational effectiveness of online homework in improving student performance on tests, time-on-task, frustration level, and confidence in mathematical abilities. Nevertheless, several studies examining online homework's impact on student performance in calculus have reported positive results. In particular, Hirsch and Weibel (2003) reported a statistically significant improvement in calculus final exam scores when online assignments replaced written homework. Similarly, Zerr (2007) found that calculus students using an online homework system showed improved learning outcomes over their peers using paper-and-pencil homework. Raines (2016) indicated that completing homework online appeared to positively impact students' understanding of mathematics concepts in the course. Callahan (2016) reported significant improvements in (i) retention rates, (ii) student engagement, and (iii) homework participation.

In second-semester calculus, LaRose (2010) investigated the impact of online homework on students' performance, behavior in completing the assignments, and their attitudes when it replaced ungraded handwritten homework. LaRose found that those using online homework did no worse, and in some cases better, than those who completed traditional homework. Furthermore, LaRose reported that students who completed online homework demonstrated increased attention to assignments.

*The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The author has no financial or non-financial interests directly or indirectly related to this work submitted for publication.

Researchers have also examined the effects of online homework on student performance in other college mathematics courses, including college algebra Burch and Kuo (2010); Hauk, Powers, and Segalla (2015); Hauk and Segalla (2005); Mathai and Olsen (2013); Pennington (2013), pre-calculus Babaali and Gonzalez (2015), and statistics Jonsdottir, Bjornsdottir, and Stefansson (2017). The impact of online homework in these courses mirrors gains observed in calculus coursework, with online homework at least as effective as traditional paper-and-pencil homework. These findings are consistent across platforms, with studies exploring ALEKS (Pennington, 2013), Hawkes Learning System (Babaali & Gonzalez, 2015), MyMathLab (Raines, 2016), WebAssign (Smolinsky, Olafsson, Marx, & Wang, 2019), and WeBWork (Hirsch & Weibel, 2003)).

Research must continue to examine the benefits of such systems in efficiency and productivity to students and faculty. Of note, much of the research was conducted 10–20 years ago and the need for up-to-date research in this area is highly warranted. This study aimed to evaluate the effectiveness of online homework in a first-year calculus course at a small liberal arts college. To that end, in Section 2, we identify our participants and the methods used to analyze this data. Section 3 presents the results, and Section 4 provides a discussion, including identifying the limitations of this study and the need to conduct further research.

2 Methods

A comparison study used two sections of first-semester calculus classes at a small private college in New England. Both sections were taught by the same instructor using similar teaching methods (i.e., a traditional lecture format). Both sections met three days a week for one hour and twenty minutes. The control group (N = 23, 57% female) was assigned handed-written homework. In contrast, the treatment group (N = 29, 67% female) used the online homework system bundled with the course text. All students had the same access to the instructor's office hours and tutoring center.

Homework for both groups consisted of five to ten problems from each section covered in the book, with the same due date. A teaching assistant graded the control group's written assignments on a scale from 0 to 10 for correctness and completion. The hand-graded assignments were returned at the next class meeting. Control group students also had full access to the online system for practice problems.

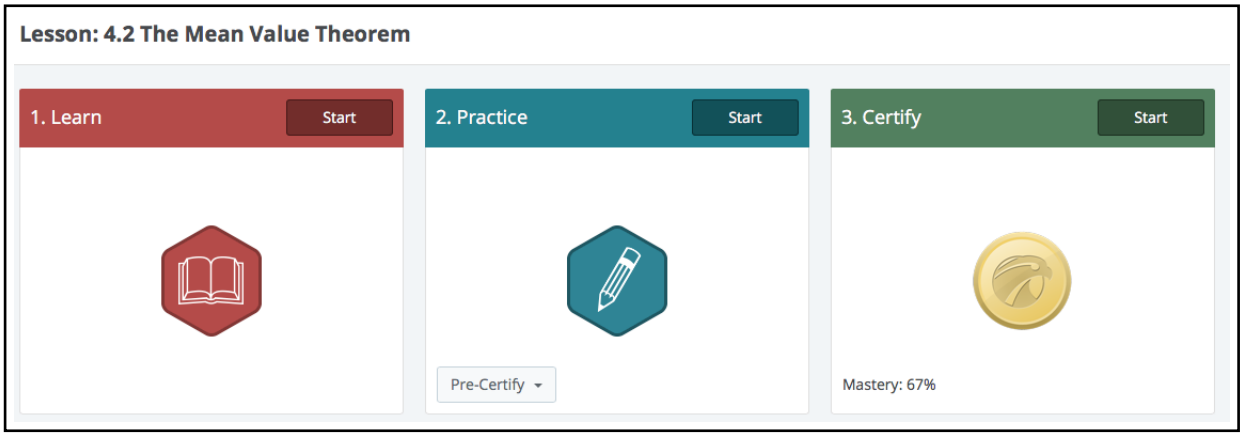
Students in the treatment group were allowed unlimited attempts before the due date. They received immediate feedback and automated assistance. However, students were required to certify (see Section 2.1) to receive credit for the assignment. This group also had equal access to the same textbook exercises as the control group. Analysis was conducted using R Statistical Software (v4.2.2) (R Core Team, 2022).

2.1 The Online Homework System

Study participants used the online homework system, Hawkes Learning System. The system is mastery-based and delivers instructional content using a three-tiered approach to support students on their path to mastery:

1. *Learn* - students read content and watch instructional videos covering the section. The content is directly associated with the eBook/Textbook and contains some interactive skill checking.
2. *Practice* - students receive extensive error feedback on their mistakes and includes step-by-step solutions.
3. *Certify* - students demonstrate mastery of the material at a defined proficiency level without access to tutoring aids to receive credit. If the student does not reach mastery, there is no penalty. Instead, students are placed back into the previous tier (i.e., Practice) and provided with custom remediation questions to target their learning needs. Students then have unlimited attempts to return to certify and demonstrate mastery of that lesson's questions. Students who certify receive full credit for the assignment, while failing to certify results in a zero on the assignment.

Figure 1: *Three-tiered online interface.*



2.2 Statistical Methods

To determine whether the treatment yielded statistically significant results, we compared the mean scores of the control and treatment groups for all in-class quizzes, the course midterm, and the final exam. For each, we test whether there is a difference between the mean score of the control and treatment groups. Our tests assume equal variance between groups based on the results of an F-test statistic ($p = 0.0965$).
In addition, a six-question survey examining students' attitudes toward homework was administered during the last week of the semester to both groups in this study. The survey items of agreement were:

1. Homework prepared me for exams and quizzes.
2. Homework was important to my learning.
3. I am confident in my math abilities.
4. I like mathematics.
5. I received prompt feedback on my homework.
6. I spent too much time on homework.

The survey used a 5-point Likert scale ($-2 =$ Strongly Disagree, $-1 =$ Disagree, $0 =$ Neutral, $1 =$ Agree, $2 =$ Strongly Agree) to measure responses. To determine contingencies and simplify the analysis, we combined the *agree* and *strongly agree* responses into one category and the *disagree* and *strongly disagree* with another, then performed a chi-square test for independence.

3 Results

The means and standard deviations for each assessment component are contained in Table 1. Statistical tests confirm a significant difference between groups on quizzes and the final exam favoring the experimental group. However, no statistically significant difference was found on the midterm.
The survey data suggest that students using a web-based homework system indicate stronger overall agreement with the prompts. In particular, students who completed online homework reported greater confidence in their mathematical abilities, spent less time on homework, acknowledged prompt feedback, and expressed higher overall enjoyment of mathematics (see Figure 2). Eighty-one percent of the students in the treatment group agreed with the statement, "I like mathematics," compared to 61% in the control group. According to a χ^2 test, this difference was significant (see Table 2). Traditional students felt they spent too much time on homework compared to the treatment group. Additionally, we note that the retention rate for the treatment group was slightly higher than the control group (93% versus 87%). However, the absolute number of students that dropped from each section was nearly equal (2 and 3, respectively).

Table 1: *Mean and standard deviation, rounded to the nearest tenth, of both groups' midterm exam, final exam, and quiz average. A p-value < 0.05 represents a significant difference in mean between online and traditional on a given assessment.*

	Online		Traditional		
Assessment	N	Mean (SD)	N	Mean (SD)	p-value
Midterm	29	79 (17.0)	23	75 (18.2)	0.2173
Final	27	81 (16.7)	20	72 (19.3)	0.04282*
Quizzes	27	83 (9.7)	21	74 (14.5)	0.004695*

Figure 2: *Survey responses grouped by Item (top/Control, bottom/Treatment). Dark orange represents strongly disagree, light orange (disagree), light blue (agree), and dark blue (strongly agree).*

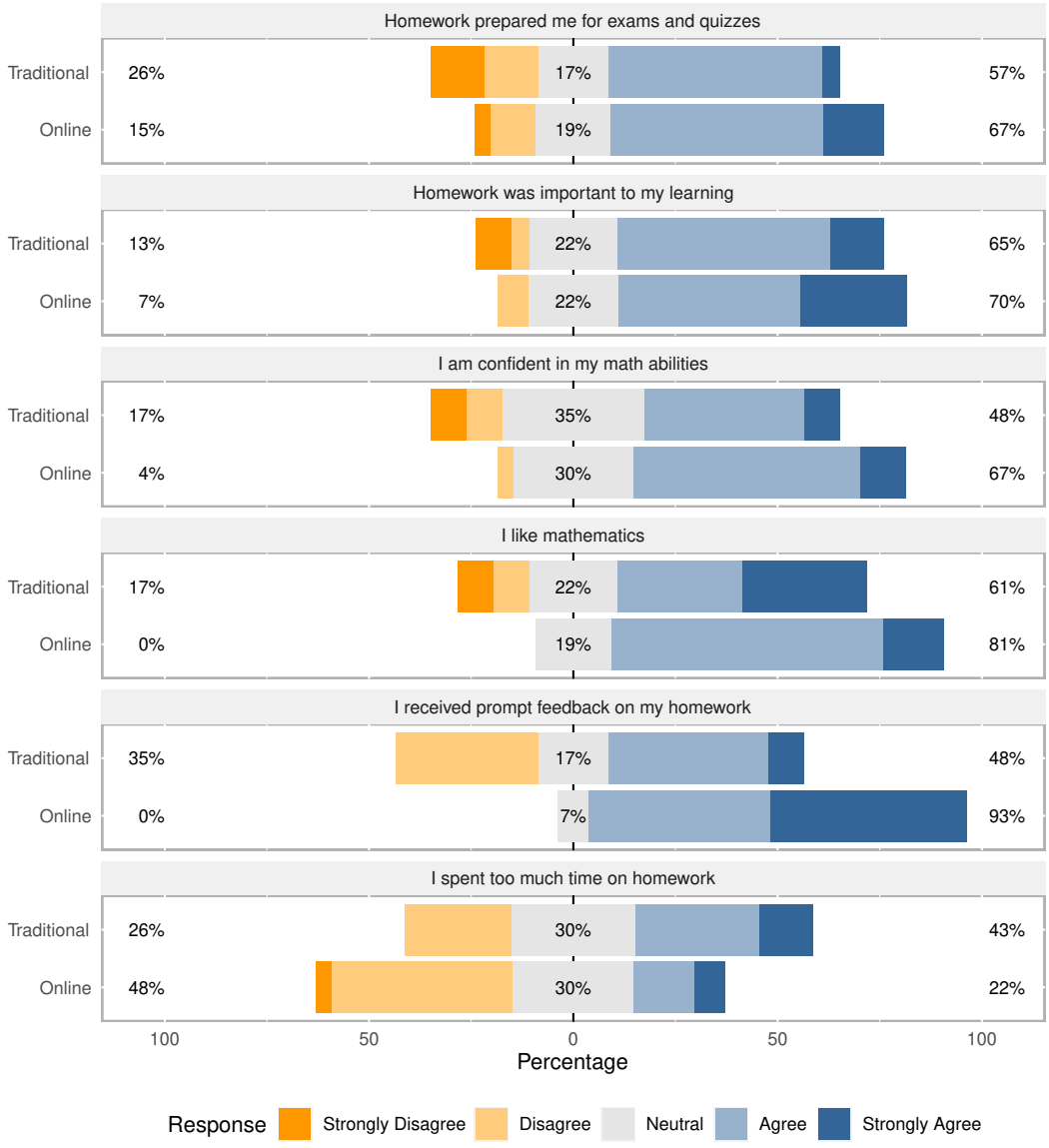


Table 2: *Tabulated agreement results on the six items by group. χ^2 test for independence used for statistical evidence of differences between groups. Significant p-values indicated by asterisks.*

	Online		Traditional		
Question	Agree	Disagree	Agree	Disagree	p-value
Preparation	18	4	13	6	0.3192
Helped Learn	19	2	15	3	0.5059
Confident	18	1	11	4	0.0802
Like math	22	0	14	4	0.0198*
Prompt feedback	25	0	11	8	0.0003*
Too much time	6	13	10	6	0.0674

4 Discussion and Conclusions

The results of this study revealed that students using the web-based homework system outperformed their counterparts who completed written homework on quizzes and the final exam. Although no statistically significant difference was found in midterm scores, this could be attributed to the familiarity with the exam content, which focused on differentiation rules and concepts covered in high school calculus. In contrast, the final exam covered less familiar topics, including Riemann sums, the Fundamental Theorem of Calculus, integration techniques, and applications of integrals.

It is worth noting that students using the online system had the advantage of reviewing and reattempting homework assignments without penalty. The median time spent on each lesson, including the Learn, Practice, and Certify components, was 50 minutes. However, the median certification time was only 15 minutes. Further analysis is needed to determine if the logged time in the system accurately reflects actual time spent on-task, as research often suggests a correlation between time spent on-task and performance (Hannula, 2004; Lee & Choi, 2011; Raudenbush & Rowan, 1996).

On the other hand, students in the traditional homework section frequently sought assistance through instructor office hours, whereas only two students from the treatment group utilized this resource. This discrepancy may be attributed to the online system's immediate feedback feature providing detailed problem explanations. This finding is consistent with previous research in the literature.

There are several limitations of this study. First, the results cannot be generalized to other populations due to the small sample size, lack of proper random assignment, and homogeneity of students regarding race/ethnicity, field of study, and socio-economic backgrounds. Additionally, controlling for instructor effects was limited by the inability to control for potential time-of-day effects. Nevertheless, efforts were made to arrange back-to-back sections spanning 11:00 am - 2:00 pm. Furthermore, the study needed more means to verify who completed the online homework, which may have implications for the validity of the results.

As online homework systems become increasingly prevalent in calculus courses, future studies should continue to investigate their impact on student performance and attitudes, considering diverse demographic factors (Tucker, 1996). Positive outcomes in this area can potentially impact retention rates in STEM disciplines. This is an exciting time in mathematics education as we strive to enhance the effectiveness of our courses and programs, necessitating continuous investigation and evaluation of these efforts. Therefore, further research on this critical area of mathematics education is crucial.

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