Fall 2022
Volume 13, Issue 2

# ALOHA: Active-Learning Office Hours & Assignments in an Online Remedial Math Course

**Kameryn Denaro, Rachel Lehman, and Alessandra Pantano**

University of California Irvine, Irvine, CA 92697

Email: kdenaro@uci.edu or rlehman@uci.edu

Keywords: precalculus, calculus, performance, gender, ethnicity, STEM

## Abstract

The performance gap between White and historically underrepresented racial or ethnic minority groups (people who are: Black, Latinx, Pacific Islanders, or indigenous to the spaces comprising the United States and its territories) is higher in online courses compared to face-to-face courses. This study investigates the educational effectiveness of incorporating face-to-face office hour sessions into an online remedial Precalculus course at a large public research university in the southwestern United States. Held in active-learning classrooms and led by the course instructor and a team of learning assistants, these sessions are specifically designed to help students succeed by providing collaborative spaces that encourage students to learn actively. Implementation of these mandatory face-to-face Active-Learning Office Hours has shown to lead to increased student performance in an online remedial Precalculus course and in the subsequent (face-to-face) Calculus course, as well as reduce gender and first-generation status performance gaps.

## Introduction

Active learning refers to classroom practices that engage undergraduates in experimenting, questioning, reflecting, discovering, inventing, and discussing with their peers and the instructor. Active-learning methods have been shown to be more effective than traditional instruction to promote academic achievement and problem-solving skills for students in science and engineering college courses (Freeman et al., 2014; Deslauriers, McCarty, Miller, Callaghan and Kestin, 2019; Theobald et al., 2020). A large mixed method study by Laursen, Hassi, Kogan and Weston (2014) showed that active learning can lead to a variety of cognitive and affective gains for students in undergraduate mathematics courses, especially for women and low-achieving students, who are often under-served by the traditional college mathematics courses. A recent study by Theobald et al. (2020) confirmed that active learning in science, technology,

 

engineering, and mathematics (STEM) courses benefits all students, but it offers disproportionate benefits for individuals from underrepresented groups by reducing achievement gaps in exam scores and passing rates. In this study we discuss the benefits of engaging students in active-learning face-to-face office hours in the context of an online remedial Precalculus course.

**Active Learning in Introductory Mathematics Courses.** Active learning in introductory undergraduate mathematics courses, like Calculus, has been the topic of many investigations as student success in these courses has been linked to persistence in STEM majors, or even persistence in college (Webb, Stade and Grover, 2014), especially for women. A study from Ellis, Fosdick and Rasmussen (2016) shows that, while controlling for academic preparedness, career intentions, and instruction, the odds of a woman being dissuaded from continuing in Calculus is 1.5 times greater than that for a man. Contrary to popular belief, students who are leaving first-year mathematics courses (and STEM fields more generally) are often as academically prepared as their persisting counterparts; poor instructional experiences in introductory level courses has often been identified as the primary reason for their departure (Rasmussen et al., 2016).

Departments of Mathematics at colleges and universities around the nation often offer Calculus courses that serve up to 1000 students per term. These large lecture-based "gateway courses" provide limited opportunities for meaningful interaction between professor and students or among students, and failure rates are high (Alzen, Langdon and Otero, 2018). Despite evidence in the literature that student-centered instruction can have significant benefits in terms of student learning (e.g., Freeman et al., 2014), and despite the call from many major leadership organizations such as the Conference Board of Mathematical Sciences to incorporate active learning in post-secondary mathematics classroom (CBMS, 2016), lecture continues to be the predominant mode of instruction in Calculus across the country (e.g., Bressoud, Mesa and Rasmussen 2015). The five-year project *Characteristics of Successful Programs in College Calculus* (Bressoud, 2012) shows that Calculus programs that support and encourage active-learning strategies lead to increased student success. Active-engagement strategies take many forms, varying from classroom-specific interventions (e.g., the use of clicker questions and other interactive student response systems during large lecture meetings) to larger instructional innovations, such as the Learning Assistant (LA) model (Alzen et al., 2018). The LA model was established at the University of Colorado Boulder in 2001. LAs are undergraduate students, trained through a pedagogy course and weekly meetings with the course instructor, which are tasked with facilitating student active engagement in the classroom. LAs facilitate group discussions and focus on eliciting student thinking and conceptual understanding. Research has shown that exposure to LAs leads to more positive learning outcomes in STEM courses, particularly among students from groups that are traditionally underrepresented in college and in STEM (Talbot, Hartley, Marzetta and Wee, 2015; Alzen et al., 2018). These results are consistent with Tinto's integration framework, which emphasizes the effects of student engagement and integration on retention, especially in the first year of college (Tinto, 2004).

 

The use of LAs is attractive because a substantial proportion of students in both 2- and 4-year colleges enter higher education underprepared for college-level study of mathematics (Biswas, 2007). In the case of California, about 85% of first-year college students are referred to developmental mathematics courses, and the majority of them are placed into courses two levels below college-level math (Fong, Melguizo and Prather, 2015). Developmental education is costly to both the students and the states, so many institutions are moving to online instruction (Jaggars and Xu, 2010). However, not all students have the strong self-directed learning skills that are required for success in online courses (Xu and Jaggars, 2014). According to a study by Kaupp (2012), the performance gap between White and Hispanic students is higher in online courses than in face-to-face courses. Xu and Jaggars (2014) also found that, while all types of students experienced decrements in performance in online courses, the decline was stronger for historically underrepresented racial or ethnic minority groups and for students with lower grade point averages. This is partly due to feelings of interpersonal isolation and a lack of engagement in the learning process (Xu & Jaggars, 2014).

The education literature shows increased attention to strategies to incorporate active learning in online mathematics courses, for example through the use of interactive discussions by video conferencing and active-learning exercises on online social learning platforms like Piazza (Irani and Denaro, 2020). Recent work by Cung, Xu, Eichhorn and Warschauer (2019) investigates the benefits of engaging students from online developmental mathematics courses in small group problem sessions, comparing three modalities of implementation: face-to-face interaction, Scribblar, and VirBELA. The study reveals that a blended setting that combines face-to-face instruction with an online intelligent learning system (ALEKS) leads to higher academic gains for students.

## The ALOHA Project

This study examines the educational effectiveness of incorporating active-learning-style office hours into an online remedial mathematics course at a large public university, which is home to nearly 40,000 undergraduates (36% PEER, 48% first generation, 37% low income) and is both a Hispanic-Serving Institution (HSI) and an Asian-American and Native American Pacific Islander Serving Institution (AANAPISI). This institution is well regarded for its ability to support underserved student communities and has received strong accolades in the press for its upward mobility rate, affordability, academic excellence, and early-career earnings. Students who major in STEM programs graduate at high rates. For students who were part of the 2012 to 2014 incoming classes, the percentage of students who started as STEM majors and graduated in four years is high (Biological Sciences 72%, Chemistry 76%, Mathematics 76%, and Engineering 62%). These figures are all higher than the national rates for these programs (Almatrafi, Johri, Rangwala and Lester, 2017; Chen, 2013). Yet these data mask a problem. In line with national trends (Olson and Riordan, 2012), a significant number of these intended STEM graduates are leaving with degrees in non-STEM fields.

 

For most STEM majors, Differential Calculus is the first mathematics course they take in college and is also one of the biggest obstacles towards their STEM degree. Student placement into Differential Calculus is based on the score on the math portion of the SAT (650 or above), the math score on the ACT exam (29 or above), or the math score on the AP Calculus AB test (3 or above). Students wishing to enroll in Differential Calculus who do not meet these requirements have two other options. They can either complete a Precalculus course, with a grade of C or better, or take an online, proctored, ALEKS (www.aleks.com) placement exam and score 80% or above. In 2012, the Precalculus course was moved completely online to give students a chance to take this remedial course in the summer prior to their arrival on campus, and hence start their first year "on track", by taking credit-bearing courses. Even though students have an opportunity to complete it in the summer, many students still wait until the Winter quarter to attempt Precalculus.

Despite efforts to create an online community, anecdotal evidence told a story that students felt alienated during the course. Given its asynchronous, online nature, students did not know their professor or classmates and felt like they had no one to talk to. In addition, they felt frustrated and discouraged by their need to take a remedial course. To mitigate the struggles faced by students, ALOHA (Active-Learning Office Hours & Assignments) was created in Fall 2018 to provide both academic and social support to students in this online, Precalculus environment. In its first iteration, the program was optional; as an incentive for participation, the students' lowest quiz score was dropped in return for attending 10 ALOHA sessions. The next quarter (Winter 2019) attendance in the program was made mandatory and was worth 7% of students' overall grade in the course.

ALOHA sessions take place on campus weekly during regularly scheduled discussion sessions. Students are instructed to bring their own laptop, student identification, and scratch paper. The ALOHA sessions aim to deepen the student's mathematical understanding of topics discussed during the course lectures. During the 50-minute meetings, students actively work to complete worksheets (see Supplemental Materials) in small groups of 3-5 students with the assistance of the instructor and Learning Assistants (LAs).

The ALOHA sessions begin in the second week of each ten-week quarter of instruction to allow the instructor enough time to gather the student's initial assessment data necessary to effectively create the active-learning worksheets. Each ALOHA session enrolls approximately 100 students and is facilitated by 3-6 LAs and the instructor. The LAs are undergraduate students who have already passed Calculus with outstanding results and have received general pedagogy training. In addition, they meet weekly with the instructor to make sure that they have mastered the subject matter. During the ALOHA sessions, the instructor and the LAs facilitate student learning through group interactions. Students explore their ideas and have the opportunity to make mistakes before the instructor steps in to explain. Sessions are held in active-learning classrooms,

 

specifically designed to help students succeed by providing collaborative spaces that encourage students to learn actively (Figure 1).

**Figure 1. The Active Learning Classrooms**

The online Precalculus course utilizes an advanced adaptive learning program called ALEKS (www.aleks.com), which provides real-time data on students' understanding and identifies what each student knows or does not know, but more importantly is ready to learn. Prior to each ALOHA session, the instructor prepares a worksheet containing ALEKS problems that students are struggling with. Many of these topics will appear again on ALEKS quizzes and examinations, hence students are motivated to attend. Group assignments change each week, based upon students' mastery of the week's materials (assessed in real-time through ALEKS). Weaker students are mixed with others who exhibit a moderate knowledge of the topic, to maximize effectiveness of peer interaction and make sure that students can learn from each other (Figure 2).

**Figure 2. ALOHA Sessions in Action**

As Precalculus is an online class, the ALOHA program is intended to benefit student learning in multiple ways. Not only does it allow for repeated exposure to the course material, but it gives students an opportunity to meet each other in a face-to-face setting and learn actively together. This in turn should allow for students to feel connected with their peers in the course and ideally gain confidence in mathematics.

**Research Aim of the Study.** This study examines whether participation in face-to-face "active-learning" office hours can improve student performance in an online Precalculus course at a large public university. Specifically, we address the following questions:

> RQ1: What is the impact of adding face-to-face active learning office hours and assignments (ALOHA) on student performance in an online Precalculus course?
>
> RQ2: To what extent does adding face-to-face ALOHA to an online Precalculus course impact future performance in an in-person differential Calculus course?

## Methods

**Participants and Student Demographics.** Students who took Precalculus in Winter 2018 (W18, $n_1$= 200) and Winter 2019 (W19, $n_2$= 226) were included in this study. 38% of the students were enrolled in a science, technology, engineering, or mathematics (STEM) related major (62% were non-STEM majors), two thirds of students were female, over 40% were designated as low-income students (based on Pell grant eligibility), and more than half self-reported as first-generation college students. About 63% of students self-reported their ethnicity as Black, Latinx, Pacific Islander or as a person indigenous to the spaces comprising the United States and its territories--we define these students as a group to be persons excluded because of their ethnicity or race (PEERs) (Asai, 2020). Average SAT scores were about 542 in Math, 551 in Reading, and 535 in Writing. The percent of students by demographic characteristics are included in Table 1 separated by whether or not the student was required to participate in ALOHA and by cohort (first-year and non-first-year students). Demographic characteristics include gender, first-generation status, under-represented racial or ethnic minority status (people who are: Latino/a/x, Black, Pacific Islanders, or indigenous to the US and its territories), and low income status. Previous academic performance measures include SAT Math, Reading, and Writing scores and first Fall quarter GPA. Data was also collected on current academic performance measures including homework, quiz, midterm, and common final exam scores as well as GPA of other courses (GPAO) taken in the same quarter as Precalculus. Future academic performance measures include common final exam scores in Differential Calculus, persistence in Differential Calculus, and GPAO taken in the same quarter as Differential Calculus. Exclusion criteria were: (1) transfer students and (2) students who were repeating the course. This study was approved by the institutions local Institutional Review Board (IRB #2018-4211) to study the educational effectiveness of incorporating active learning into an online course.

 

| | First-year students | | | Non first-year students | | | All students | | |
|---|---|---|---|---|---|---|---|---|---|
| | no ALOHA | ALOHA | | no ALOHA | ALOHA | | no ALOHA | ALOHA | |
| **Students who are:** | W18 | W19 | Total | W18 | W19 | Total | W18 | W19 | Total |
| Low Income | 42 | 41 | 41 | 55 | 42 | 47 | 46 | 41 | 43 |
| non-Low Income | 58 | 59 | 59 | 45 | 58 | 53 | 54 | 59 | 57 |
| First Generation | 68 | 63 | 65 | 66 | 49 | 56 | 68 | 58 | 62 |
| non-First Generation | 32 | 37 | 35 | 34 | 51 | 44 | 32 | 42 | 38 |
| Female | 72 | 65 | 69 | 70 | 72 | 71 | 72 | 68 | 69 |
| non-Female | 28 | 35 | 31 | 30 | 28 | 29 | 28 | 32 | 31 |
| PEERs | 65 | 60 | 62 | 59 | 67 | 64 | 63 | 63 | 63 |
| non-PEERs | 35 | 40 | 38 | 41 | 33 | 36 | 37 | 37 | 37 |
| | n = 144 | n = 140 | n = 284 | n = 56 | n = 86 | n = 142 | n = 200 | n = 226 | n = 426 |

**Table 1. Percent of students in each demographic group.** The percentage of students in each demographic category is split by whether they participated in ALOHA and whether or not they were a first-year student.

**Timing and Structure.** Both the W18 and W19 online courses ran on a weekly cycle over a ten-week period. The mathematical content was broken into six parts within ALEKS, called Intermediate Objectives (IOs), in order to keep the students on similar tracks while giving flexibility and time for students to learn at their own pace. The course had approximately 140 lecture videos averaging from 2 to 9 minutes in length. The instructor analyzed the ALEKS reports daily to gauge which topics the students were struggling with in order to suggest appropriate video content corresponding to these topics. Both courses had four quizzes, one midterm, six IOs, and a common final exam.

**Office Hours**. In Winter 2018, the instructor offered a total of 10 hours of office hours per week: 2 were face-to face and 8 were online. The online office hours were hosted using Scribblar (http://www.scribblar.com/), an online collaborative whiteboard (Figure 3). During office hours, students had the opportunity to ask the instructor questions and interact with their peers. Office hours were not mandatory, but they were highly recommended. In Winter 2019, the instructor offered 7 hours of office hours per week: 2 were face-to-face, 2 were online (through Scribblar, by appointment only), and 3 were ALOHA sessions. Participation in (at least) one ALOHA office hour per week was mandatory.

 

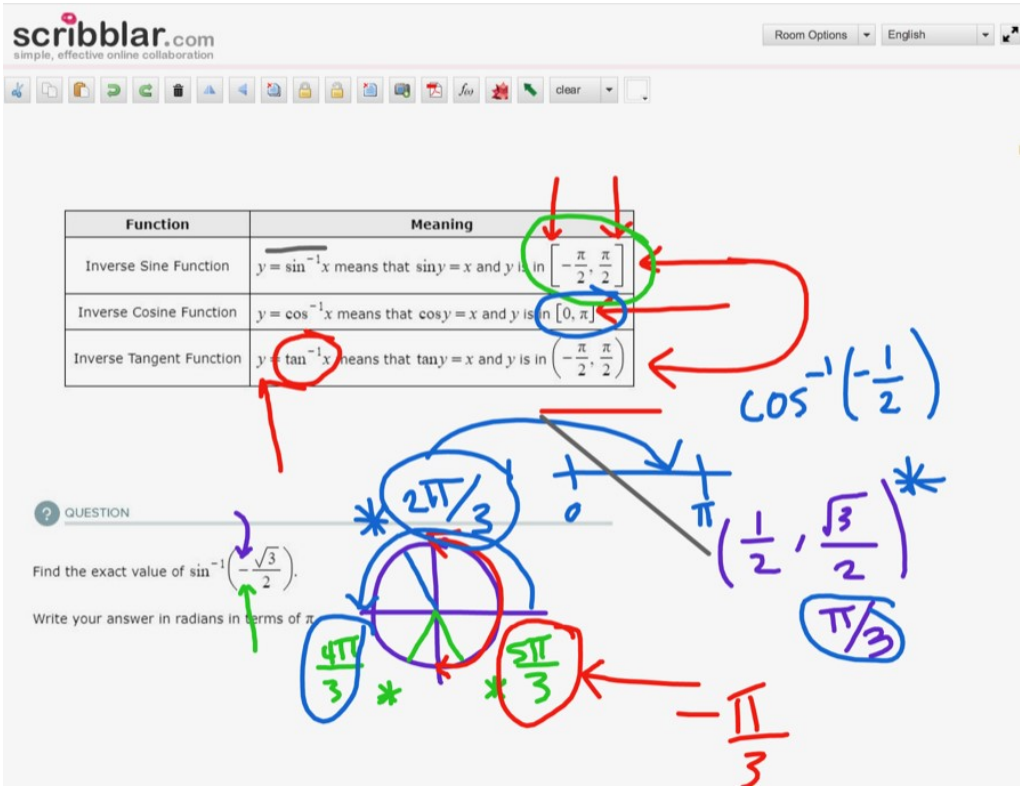


**Figure 3. Office hours using an online collaborative whiteboard (Scribblar).**

The main goal of this study is to test whether the implementation of mandatory face-to-face ALOHA office hours impacted student performance in the online Precalculus course. We compare two offerings of the course: Winter 18 (without ALOHA) and Winter 19 (with ALOHA). Because the common final exam for these two offerings of Precalculus had similar questions and structure (differing only by the ordering of the questions, and the specific numbers, variables or graphs used in the questions), test performance on the common exam is used as a basis for measuring learning outcomes in the study. The data is analyzed using quantile regression (Koenker, 2000); this robust regression method was chosen in place of mean regression (i.e. ordinary least squares regression) because the assumption of the errors being roughly normal for the mean regression is violated in our dataset. Using this model, we evaluate the effect of ALOHA while taking into account other factors and demographic characteristics (GPAO, SAT Math scores, first-generation status, PEER status, and gender). To obtain the quantile specific regression parameters and respective confidence intervals we use the R package *quantreg* (Koenker, 2018). The estimated coefficients and respective 95% confidence intervals from the median regression model are presented in Table 4-5. Quantile regression methods are implemented in numerous research areas (Casady and Cryer, 1976; Daouia et al., 2011; Portnoy and Koenker, 1997; Eide and Showalter, 1998; He and Shi, 1998; Zhou and Portnoy, 1998; Moller et al., 2008; Ma and He, 2014; Zhang et al., 2017; Xiong and Tian, 2019; Denaro et al., 2020).

 

## Results

A comparison of course outcomes for students in the Precalculus course, either in Winter 2018 (without ALOHA) or in Winter 2019 (with ALOHA) is highlighted in Table 2. Also included in the table are data about the performance of these students in Differential Calculus in the spring directly following Precalculus. First-year students in ALOHA benefited from the ALOHA program with higher performance on the quizzes, midterms, and common final exam. This additionally had a carry-over effect the following quarter with the students mastering more topics as demonstrated on the common final exam of Differential Calculus taken in a face-to-face format.

| | First-year students | | | Non first-year students | | | All students | | |
|---|---|---|---|---|---|---|---|---|---|
| | no ALOHA W18 | ALOHA W19 | Total | no ALOHA W18 | ALOHA W19 | Total | no ALOHA W18 | ALOHA W19 | Total |
| **Previous Academic Performance** | | | | | | | | | |
| SAT Math | 543 (64) | 546 (63) | 545 (63) | 536 (66) | 539 (55) | 538 (60) | 541 (64) | 543 (60) | 542 (62) |
| SAT Reading | 556 (79) | 548 (79) | 552 (79) | 541 (77) | 556 (87) | 550 (83) | 552 (79) | 551 (82) | 551 (80) |
| SAT Writing | 533 (67) | 533 (72) | 533 (69) | 535 (65) | 540 (71) | 538 (69) | 534 (66) | 535 (71) | 535 (69) |
| First Fall Quarter GPA | 2.64 (0.94) | 2.75 (0.77) | 2.69 (1.00) | 2.73 (0.94) | 2.57 (0.82) | 2.63 (1.00) | 2.66 (0.94) | 2.68 (0.80) | 2.67 (1.00) |
| **Precalculus** | | | | | | | | | |
| Quiz 1 | 78 (24) | 84 (18) | 81 (21) | 83 (20) | 82 (24) | 83 (23) | 79 (23) | 83 (20) | 81 (22) |
| Quiz 2 | 77 (21) | 82 (20) | 80 (21) | 80 (18) | 80 (23) | 80 (21) | 78 (20) | 81 (21) | 80 (21) |
| Quiz 3 | 79 (23) | 88 (14) | 83 (20) | 80 (23) | 81 (24) | 80 (24) | 79 (23) | 85 (19) | 82 (21) |
| Quiz 4 | 77 (20) | 82 (18) | 79 (20) | 78 (27) | 76 (26) | 77 (26) | 77 (22) | 80 (22) | 78 (22) |
| Midterm | 71 (23) | 82 (18) | 76 (21) | 79 (18) | 77 (19) | 78 (18) | 73 (22) | 80 (18) | 77 (20) |
| Final | 59 (23) | 72 (19) | 65 (22) | 63 (24) | 67 (22) | 66 (23) | 60 (23) | 70 (20) | 65 (22) |
| Grade | 2.38 (1.24) | 2.95 (1.04) | 2.67 (1.00) | 2.65 (1.29) | 2.51 (1.29) | 2.57 (1.00) | 2.46 (1.26) | 2.79 (1.15) | 2.63 (1.00) |
| Winter GPAO | 2.80 (0.88) | 2.81 (0.75) | 2.80 (1.00) | 3.14 (0.72) | 2.95 (0.86) | 3.02 (1.00) | 2.89 (0.85) | 2.86 (0.80) | 2.88 (1.00) |
| Passed Precalculus | 75% | 91% | 83% | 79% | 74% | 76% | 76% | 85% | 81% |
| **Differential Calculus** | | | | | | | | | |
| Common Final Grade | 39 (17) | 50 (16) | 44 (17) | 44 (17) | 40 (20) | 42 (19) | 40 (17) | 45 (19) | 43 (18) |
| Spring GPAO | 1.66 (1.22) | 2.01 (1.25) | 1.81 (1.00) | 1.62 (1.32) | 1.52 (1.31) | 1.56 (1.00) | 1.65 (1.24) | 1.79 (1.29) | 1.72 (1.00) |
| Took Differential Calculus in Spring | 2.93 (0.98) | 3.00 (0.85) | 2.96 (1.00) | 3.29 (0.82) | 3.07 (0.96) | 3.16 (1.00) | 3.03 (0.95) | 3.02 (0.89) | 3.03 (1.00) |
| | 59% | 54% | 56% | 54% | 66% | 61% | 57% | 58% | 58% |
| | n = 144 | n = 140 | n = 284 | n = 56 | n = 86 | n = 142 | n = 200 | n = 226 | n = 426 |

**Table 2. Summary statistics.** The summary statistics for previous, current, and future academic performance is displayed for Precalculus students who took ALOHA versus those who did not. For the quantitative variables the mean is displayed and the standard deviation is in parenthesis. For whether or not the student(s) passed Precalculus and whether or not the student(s) took differential Calculus in the following quarter, the percentage is given.

*RQ1: What is the impact of adding face-to-face active learning office hours and assignments (ALOHA) on student performance in an online Precalculus course?*

Students who took ALOHA (Winter 2019) outperformed students who did not (Winter 2018) on the common final for the Precalculus course as shown in Figure 4. Table 3 gives the summary statistics of the Precalculus common final performance split by demographics, comparing students from Winter 2018 (without ALOHA) and Winter 2019 (with ALOHA). All sub-groups benefited from ALOHA, with the exception of the gender subgroups for non-first year students. Both non-PEER and PEER students improved by at least 10% on average. The data supports the claim of Laursen et al. (2014) that while all students benefit from the use of active learning in mathematics classrooms, female students get significantly higher gains than males, and in our case that resulted in closing the gap between male and female performance. The gap between non-first-generation college students and first-generation college students was 9% in Winter 2018 and narrowed in Winter 2019 (6% difference).

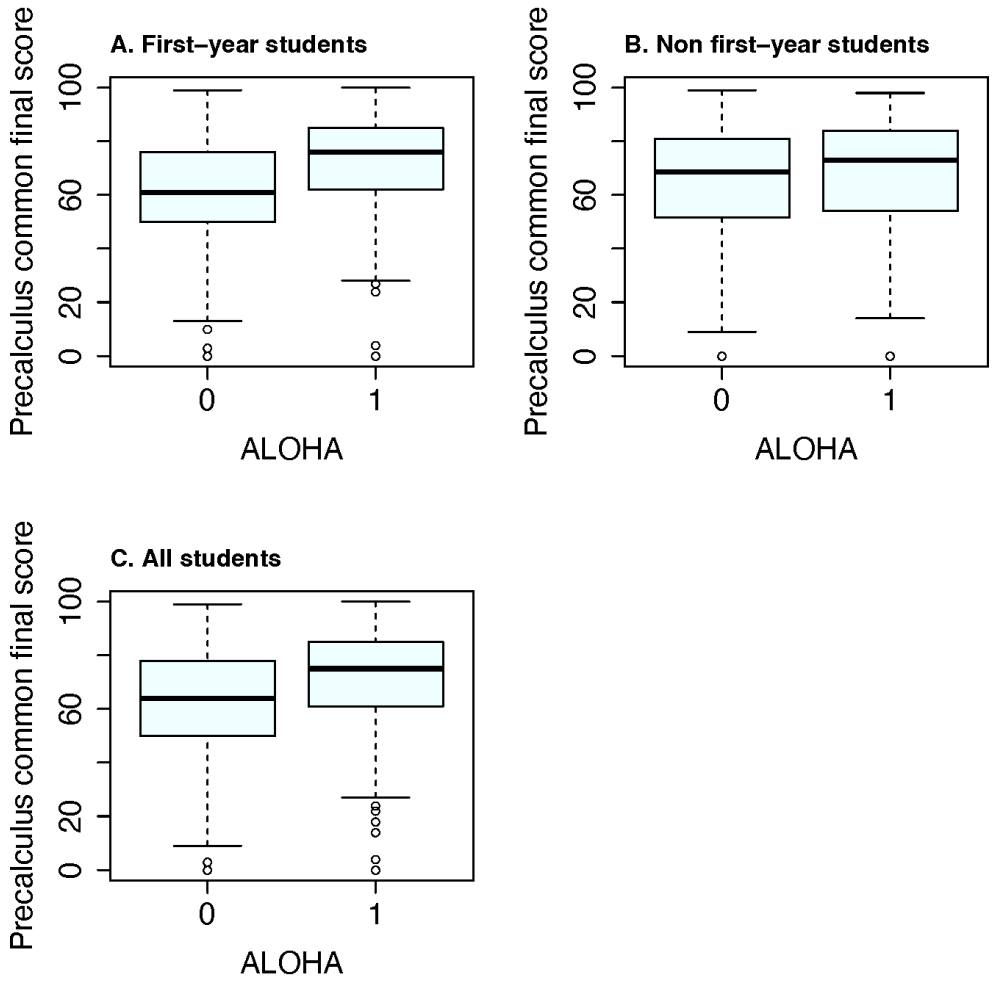


**Figure 4. Precalculus common final performance.** (A) includes the first-year students, (B) includes the non first-year students, and (C) includes all students.

 

| | First-year students | | | Non first-year students | | | All students | | |
|---|---|---|---|---|---|---|---|---|---|
| **Students who are:** | no ALOHA W18 | ALOHA W19 | Gain | no ALOHA W18 | ALOHA W19 | Gain | No ALOHA W18 | ALOHA W19 | Gain |
| Low Income | 55 (28) | 72 (17) | 17 | 59 (26) | 78 (12) | 19 | 56 (27) | 75 (16) | 19 |
| non-Low Income | 66 (20) | 72 (19) | 6 | 66 (16) | 74 (17) | 8 | 66 (18) | 72 (18) | 6 |
| First Generation | 63 (26) | 73 (16) | 10 | 61 (19) | 75 (14) | 14 | 62 (24) | 74 (16) | 12 |
| non-First Generation | 62 (24) | 72 (21) | 10 | 58 (15) | 72 (16) | 14 | 61 (21) | 72 (19) | 11 |
| Female | 61 (21) | 72 (19) | 11 | 74 (14) | 74 (15) | 0 | 65 (20) | 72 (18) | 7 |
| non-Female | 51 (29) | 79 (14) | 28 | 66 (17) | 65 (21) | -1 | 55 (27) | 75 (16) | 20 |
| PEERs | 63 (19) | 75 (14) | 12 | 60 (21) | 76 (19) | 16 | 62 (19) | 75 (16) | 13 |
| non-PEERs | 60 (27) | 71 (21) | 11 | 64 (27) | 71 (13) | 7 | 61 (27) | 71 (19) | 10 |

**Table 3. Mean and standard deviation split by demographics.** The average gain on the Precalculus common final for ALOHA (Winter 2019 versus Winter 2018) are displayed for each of the sub-groups.

In order to examine, to what extent participation in face-to-face "active-learning" office hours can improve student performance after controlling for demographic characteristics (PEER status, gender, first-generation status, and low-income status) and academic performance (SAT Math scores, first-quarter Fall GPA, and GPA of other courses taken in the same quarter) we fit a median regression model. Figure 5 displays the common final scores in Precalculus versus the GPA of other courses taken in the same term (GPAO) as well as the median regression line and respective confidence bands. If we compare students with similar GPAOs during Precalculus, we see there is a difference in the performance on the common final for students who took ALOHA versus those who did not. Table 4 displays the quantile regression model with Precalculus common final exam performance as the response and the following predictors: academic performance (Fall first-quarter GPA, Winter quarter GPAO, and standardized SAT Math scores), demographic characteristics (whether or not students are first-generation, low-income, female, or PEERs), and whether or not it is the students first-year at university. Adding ALOHA to an online mode of instruction resulted in improved academic outcomes, this was especially true for first-year students (significant interaction between ALOHA and non first-year students). The median final exam score in the online course with ALOHA was 14% higher than the online course which did not include ALOHA for first-year students, while holding academic performance and demographic characteristics constant.

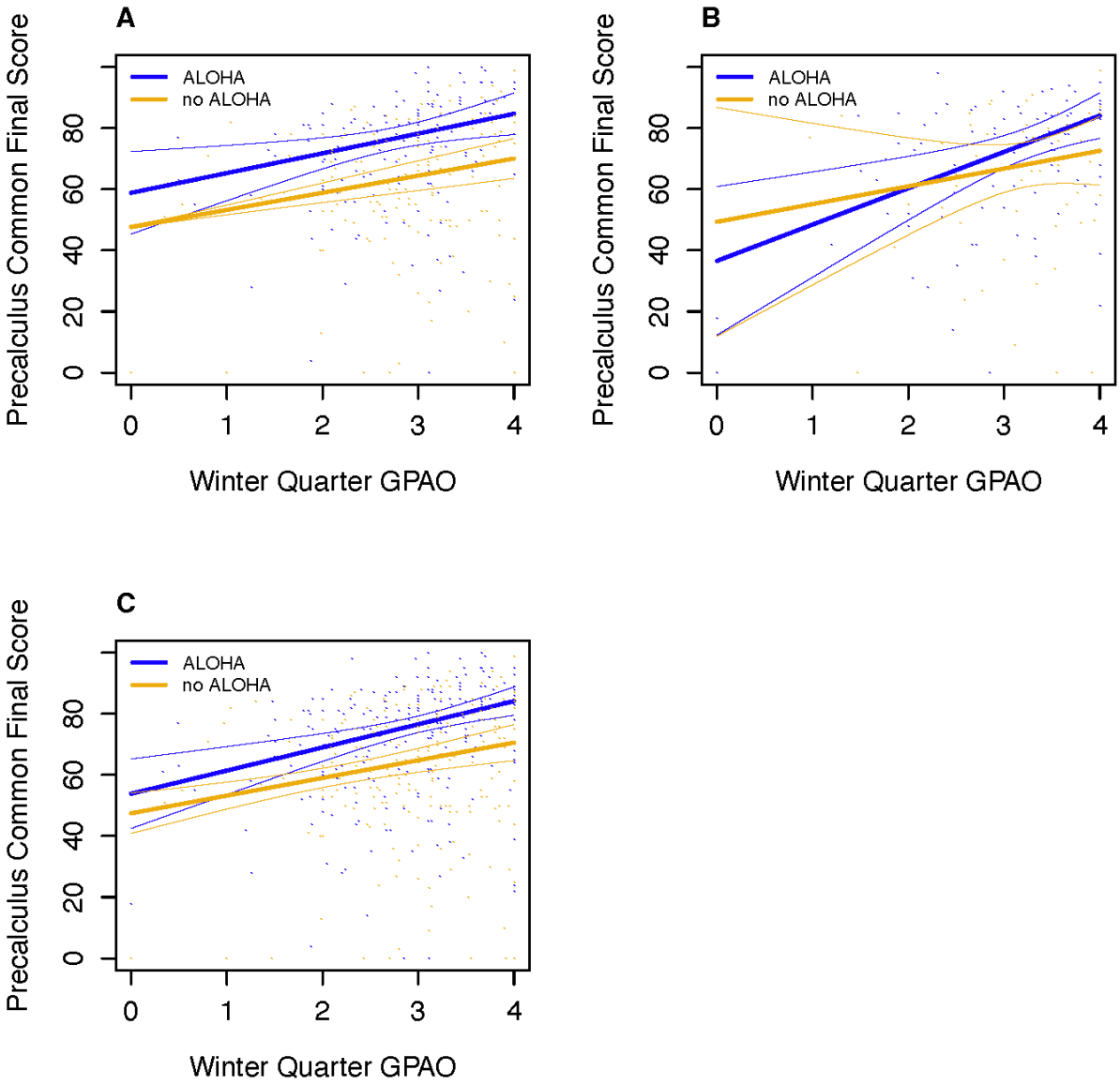


**Figure 5. Scatterplot of Precalculus common final scores and GPAO.** The response variable is the Precalculus common final score and the GPA of other courses taken in the same term (GPAO) is the explanatory variable. The fitted median regression line, and respective standard errors, for the ALOHA (Winter 2019) and non-ALOHA (Winter 2018) students are displayed. (A) includes the first-year students, (B) includes the non first-year students, and (C) includes all students.

| | Coefficients | 95% Confidence Interval |
|---|---|---|
| Intercept | 39.80 | (33.06, 49.75)* |
| Treatment | | |
| RG: no ALOHA | | |
| ALOHA | 14.13 | (9.77, 16.83)* |
| First-year student | | |
| RG: Yes | | |
| No | 3.52 | (-0.58, 8.98) |
| Previous Academic Performance | | |
| Standardized SAT Math Scores | 5.01 | (2.82, 6.87)* |
| First-Quarter Fall GPA | 3.80 | (0.93, 6.33)* |
| Winter Quarter GPAO | 5.15 | (3.27, 7.80)* |
| First Generation (FG) Status | | |
| RG: non-FG | | |
| FG | -3.38 | (-6.99, -0.44)* |
| Low Income (LI) Status | | |
| RG: non-LI | | |
| LI | 0.95 | (-3.92, 3.44) |
| Female Status | | |
| RG: non-female | | |
| Female | -0.91 | (-3.05, 4.32) |
| PEER Status | | |
| RG: non-PEER | | |
| PEER | 0.85 | (-2.79, 4.35) |
| Interactions: | | |
| ALOHA and Non First-Year Students | -10.21 | (-16.83, -1.47)* |

**Table 4. Performance on the Precalculus common final exam.** The coefficients as well as the respective 95% confidence intervals are displayed for the median regression line. The reference group for each categorical variable is labeled RG.

*RQ2: To what extent does adding face-to-face ALOHA to an online Precalculus course impact future performance in an in-person differential Calculus course?*

There was a positive impact of ALOHA for Precalculus students who went on to take Differential Calculus the following quarter. The carry-over effect in terms of overall performance on the common final and grade in Differential Calculus is displayed in Table 2. Additionally, we see that there are gains on the Differential Calculus common final for first-year students who are PEERs and for non-first year students who are Female (Table 5).

| | First-year students | | | Non first-year students | | | All students | | |
|---|---|---|---|---|---|---|---|---|---|
| **Students who are:** | post-no ALOHA S18 | post-ALOHA S19 | Gain | post-no ALOHA S18 | post-ALOHA S19 | Gain | post-no ALOHA S18 | post-ALOHA S19 | Gain |
| Low Income | 40 (20) | 38 (25) | -2 | 49 (15) | 51 (10) | 2 | 42 (19) | 44 (21) | 2 |
| non-Low Income | 37 (18) | 45 (21) | 8 | 38 (19) | 51 (15) | 13 | 37 (18) | 47 (20) | 10 |
| First Generation | 46 (17) | 46 (22) | 0 | 34 (16) | 46 (21) | 12 | 42 (17) | 46 (21) | 4 |
| non-First Generation | 37 (22) | 48 (20) | 11 | 33 (19) | 43 (17) | 10 | 36 (21) | 46 (18) | 10 |
| Female | 42 (17) | 44 (21) | 2 | 39 (25) | 53 (17) | 14 | 41 (20) | 47 (20) | 6 |
| non-Female | 34 (16) | 42 (19) | 8 | 37 (9) | 38 (24) | 1 | 35 (15) | 41 (20) | 6 |
| PEERs | 40 (18) | 47 (23) | 7 | 47 (20) | 48 (22) | 1 | 41 (18) | 47 (23) | 6 |
| non-PEERs | 38 (21) | 42 (17) | 4 | 38 (18) | 45 (9) | 7 | 38 (19) | 43 (14) | 5 |

**Table 5. Mean and standard deviation split by demographics.** The average gain on the Differential Calculus common final post-ALOHA (Spring 2019 versus Spring 2018) are displayed for each of the sub-groups.

We fit a median regression model to our data to examine the carry-over effect of the face-to-face "active-learning" office hours on student performance in Differential Calculus. The model is displayed in Table 6 and controls for demographic characteristics (PEER status, gender, first-generation status, and low-income status) and academic performance (standardized SAT Math scores, first-quarter Fall GPA, standardized Precalculus common final scores, and GPA of other courses taken in the same quarter). It is beneficial that ALOHA participation has beneficial carry-over effects, even after controlling for student academic achievement, and those students who participated in ALOHA had improved performance on the Differential Calculus common final exam (significance at the 0.05 level denoted with an asterisk, i.e. * $p < 0.05$). In terms of the median final exam score in the following face-to-face differential Calculus class, students who previously took Precalculus with ALOHA earned a score 8% higher compared to the students that took the online course which did not include ALOHA (Table 6). For differential Calculus, we did not see differences in performance for first-year versus non first-year students. There were not significant gains for any of the demographic groups in differential Calculus that we observed. However, we note that for these students by Spring quarter the performance in Precalculus and overall performance in their other courses mattered more than SAT Math performance. These results show that implementation of Active Learning Office Hours can lead to increased student performance not only during the course that it is being implemented in, but also in subsequent courses.

| | Coefficients | 95% Confidence Interval |
|---|---|---|
| Intercept | 43.75 | (28.59, 53.46)* |
| Treatment | | |
| RG: no ALOHA | | |
| ALOHA | 8.13 | (5.04, 10.85)* |
| First-year student | | |
| RG: Yes | | |
| No | 1.69 | (-1.92, 8.12) |
| Previous Academic Performance | | |
| Standardized SAT Math Scores | 2.07 | (-0.30, 3.35) |
| First-Quarter Fall GPA | 4.19 | (0.23, 5.39)* |
| Standardized Precalculus Common Final Score | 7.43 | (5.41, 11.36)* |
| Spring Quarter GPAO | -4.92 | (-6.26, -0.16)* |
| First Generation (FG) Status | | |
| RG: non-FG | | |
| FG | -0.43 | (-5.27, 4.02) |
| Low Income (LI) Status | | |
| RG: non-LI | | |
| LI | 0.64 | (-2.64, 4.00) |
| Female Status | | |
| RG: non-female | | |
| Female | 1.24 | (-1.30, 3.53) |
| PEER Status | | |
| RG: non-PEER | | |
| PEER | -0.86 | (-4.87, 1.35) |
| Interactions: | | |
| ALOHA and Non First-Year Students | -6.08 | (-15.74, 0.34) |

**Table 6. Performance on the differential Calculus common final exam.** The coefficients as well as the respective 95% confidence intervals are displayed for the median regression line. The reference group for each categorical variable is labeled RG.

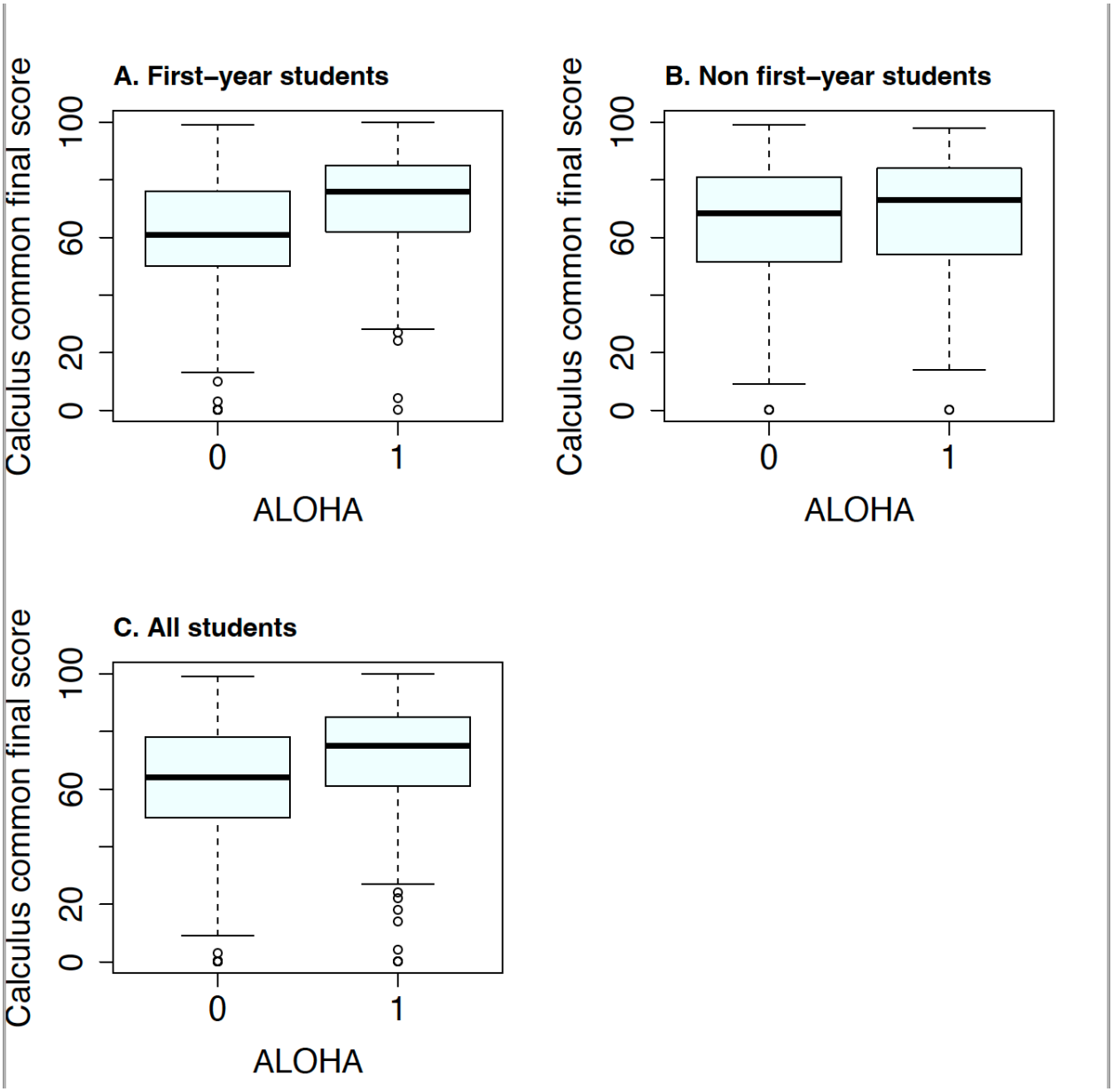


**Figure 6. Differential Calculus common final performance.** (A) includes the first-year students, (B) includes the non first-year students, and (C) includes all students.

## Discussion

Incorporating face-to-face Active Learning Office Hours and Assignments (ALOHA) to an online Precalculus course resulted in improved course performance compared to students in the online course without ALOHA. In addition, there were spill-over effects into the follow-on face-to-face Calculus course in the next quarter even after adjusting for academic preparation and other demographic factors. When considering the difference in performance for students who were exposed to the ALOHA sessions compared to those who were not, we saw an increase in overall average grades for Precalculus (no ALOHA = 2.46, ALOHA = 2.79) and for the subsequent

 

Calculus course (no ALOHA = 1.65, ALOHA = 1.79). The fact that the average grades in the subsequent Calculus course being below a 2.0 average suggests that there are still interventions that we need to consider during the following course and our future work plans to focus on improving course outcomes in those courses. However, we would also like to note that at our university for non-majors a C- or above (1.7 or above) is the requirement to obtain credit or move on in the sequence. Therefore, the students in ALOHA satisfy this requirement whereas the students without ALOHA were below this threshold on average. While we have made progress in the Precalculus sequence we also recognize that we will need to iteratively improve the ALOHA program and future programs so that we can impact subsequent courses (such as Calculus) to a greater degree. We observed a positive impact of ALOHA for Precalculus students both based on the raw score comparison (Table 2-3 and Table 5) and based on the comparison of performance after adjusting for demographic characteristics and previous academic performance (Tables 4 and Table 6). As expected, the benefits of ALOHA are stronger during the intervention on performance in Precalculus, however we see a carry-over effect of the intervention after the intervention was complete on the performance in Differential Calculus as well.

An online intelligent learning system (ALEKS) was integrated in the course design to achieve an online format which provided students with enough structure to keep them on track in an online course – a common pitfall of online courses. To increase student engagement, we utilized online tools such as Scribblar, video lectures, and online discussions. Although it can be more challenging to connect with students in an online format, we overcame this difficulty by increasing instructor presence in the class by interacting with students in the online discussions and the in-person active learning office hours, and by providing specific guidance to which videos the students needed to focus on based on current performance of a particular offering of the course and cohort of students. In addition, active learning assignments - both in the online discussions and the in-person active learning office hours, helped students find peers to collaborate with. While not explicitly measured in this paper, it is conceivable that the increased (student-instructor and student-student) interactivity resulting from the ALOHA sessions played a significant role in the success of the intervention.

Many researchers have hypothesized that the lack of human interaction in virtual learning environments may hinder student learning (e.g., Anderson, 2003; Moore, 2013), by creating not only physical separation between students and instructors, but also a psychological and communication gap (Jaggars & Xu, 2016). Recent findings (Cung, Xu & Eichhorn, 2018) show that increased interpersonal interactions, in the form of frequent instructor emails and the opportunity to meet in a physical classroom environment on a voluntary basis, can significantly improve student performance in online courses. Indeed, teacher presence can contribute greatly to the sense of belonging in the online context. Online courses that offer students multiple and varied opportunities to interact are more likely to satisfy the unique learning needs of a diverse range of students (Thomas, 2014). Fostering a sense of belonging in online courses may lead to

 

improved retention of students, especially in the first year where attrition is high for non-traditional students (Krause, 2005).

**Limitations and Future Directions.** One potential limitation of this study is the difference in office hours attendance rules for the two terms. In Winter 2018 (prior to the ALOHA intervention), the Precalculus instructor offered a total of 10 office hours per week: 2 were face-to face and 8 were online through the collaborative platform Scribblar. Although students had an opportunity to benefit from office hours, and participation in office hours was highly recommended, attendance was not mandatory. In Winter 2019 (during the ALOHA intervention), the Precalculus instructor offered 7 office hours per week: 2 were face-to-face, 2 were online (through Scribblar, by appointment only), and 3 were ALOHA sessions. Participation in (at least) one ALOHA office hour per week was required, and was worth 7% of students' overall grade in the course. This switch from voluntary attendance to mandatory attendance to office hours may have had an impact on the grades outside of the impact of the intervention. While it is possible that this change in grading scheme may have affected the raw grades in Precalculus, we note that our analysis purposely focuses on common final performance in *both* the (Winter) Precalculus course *and* the Differential Calculus course taken by students in the following Spring. The increase in grades on the common final exams for these two courses gives evidence that the ALOHA sessions are not just affecting overall course grades, but also impacting performance on common questions and topics in both Precalculus and Calculus.

Another potential limitation is the generalizability of in-person office hours compared to synchronous online office hours. This is especially important for universities who changed to remote learning imposed by the COVID-19 restrictions for face-to-face courses. Our future research includes studying the impact of synchronous online/virtual interventions, to online math courses and the extent to which the switch from an in-person to an online format for the subsequent Calculus course has an impact on academic performance.

## Conclusions

Our assessment of the ALOHA program highlights that participants in the initial, mandatory, ALOHA offering (Winter 2019) scored significantly higher on the Precalculus quizzes, midterm, and common final relative to their peers who enrolled in Precalculus prior to the ALOHA implementation (Winter 2018), and had a higher passing rate. Moreover, students in the ALOHA sessions scored significantly higher on the common final in the next math course in the Calculus series (Differential Calculus). We recommend that all departments currently utilizing an online format for their more introductory math courses do so with a combination of synchronous and asynchronous activities. Understanding the effect of particular online strategies on student engagement and ultimately learning outcomes is imperative to ensure the success of historically underrepresented students in STEM fields.

## Acknowledgements

The authors would like to acknowledge all the Learning Assistants that supported students through the ALOHA session, along with Josh Arimond, Lead Coordinator of the Certificated Learning Assistants Program, for the invaluable training in active learning provided to the Learning Assistants. We would also like to thank the Mathematics Department for their support of this program and covering the costs of hiring Learning Assistants for this course

## References

Alzen, J. L., Langdon, L. S., & Otero, V. K. (2018). A logistic regression investigation of the relationship between the Learning Assistant model and failure rates in introductory STEM courses. *International journal of STEM education*, *5*(1), 56.

Almatrafi, O., Johri, A., Rangwala, H., & Lester, J. (2017). Retention and persistence among STEM students: A comparison of direct admit and transfer students across engineering and science. In *Proceedings of ASEE Annual Meeting*.

Anderson, T. (2003). Getting the mix right again: an updated and theoretical rationale for interaction. International Review of Research in Open and Distance Learning, 4(2), 9e14.

Asai, D. J. (2020). Race matters. *Cell*, *181*(4), 754-757.

Biswas, R. R. (2007). Accelerating remedial math education: How institutional innovation and state policy interact. *Achieving the Dream policy brief for Jobs for the Future*, 1-11.

Bressoud, D. (2012). Characteristics of successful programs in college Calculus. Retrieved from http://www.macalester.edu/~bressoud/talks/2012/CSPCC_NCTM. pdf.

Bressoud, D., V. Mesa, and C. Rasmussen (Eds), 2015. Insights and Recommendations from the MAA National Study of College Calculus. Washington, DC: Mathematical Association of America.

Casady, R. J., & Cryer, J. D. (1976). Monotone percentile regression. *The Annals of Statistics*, 532-541.

Chen, X. (2013). STEM Attrition: College Students' Paths into and out of STEM Fields. Statistical Analysis Report. NCES 2014-001. *National Center for Education Statistics*.

Conference Board of Mathematical Sciences. (2016). *CBMS joint statement on active learning in postsecondary mathematics*. Retrieved from http://www.cbmsweb.org/2016/07/active-learning in-post-secondary-mathematics-education/

Cung, B., Xu, D., & Eichhorn, S. (2018). Increasing Interpersonal Interactions in an Online Course: Does Increased Instructor Email Activity and Voluntary Meeting Time in a Physical Classroom Facilitate Student Learning?. *Online Learning*, *22*(3), 193-215.

Cung, B., Xu, D., Eichhorn, S., & Warschauer, M. (2019). Getting Academically Underprepared Students Ready through College Developmental Education: Does the Course Delivery Format Matter?. *American Journal of Distance Education*, *33*(3), 178-194, DOI: 10.1080/08923647.2019.1582404

Daouia, A., Gardes, L., & Girard, S. (2013). On kernel smoothing for extremal quantile regression. *Bernoulli*, *19*(5B), 2557-2589.

 

Denaro, K., Bailey, B. A., & Conrad, D. J. (2020). Quantifying Disease Severity Of Cystic Fibrosis Using Quantile Regression Methods. *Journal of Data Science*, *18*(1), 148-160.

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences*, *116*(39), 19251-19257.

Eide, E., & Showalter, M. H. (1998). The effect of school quality on student performance: A quantile regression approach. *Economics letters*, *58*(3), 345-350.

Ellis, J., Fosdick, B. K., & Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after Calculus compared to men: Lack of mathematical confidence a potential culprit. *PloS one*, *11*(7), e0157447.

Fong, K.E., Melguizo, T. & Prather, G. Increasing Success Rates in Developmental Math: The Complementary Role of Individual and Institutional Characteristics. *Res High Educ***56,** 719–749 (2015). https://doi.org/10.1007/s11162-015-9368-9

Freeman, S., S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth. 2014. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Science*. 111(23): 8410–8415.

He, X., & Shi, P. (1998). Monotone B-spline smoothing. *Journal of the American statistical Association*, *93*(442), 643-650.

Irani, S., & Denaro, K. (2020, February). Incorporating Active Learning Strategies and Instructor Presence into an Online Discrete Mathematics Class. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 1186-1192).

Jaggars, S. S. (2014). Choosing between online and face-to-face courses: Community college student voices. *American Journal of Distance Education*, *28*(1), 27-38.

Jaggars, S., & Xu, D. (2010). Online learning in the Virginia community college system. New York, NY: Columbia University, Teachers College, Community College Research Center.

Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance?. *Computers & Education*, *95*, 270-284.

Kaupp, R. (2012). Online penalty: The impact of online instruction on the Latino-White achievement gap. *Journal of Applied Research in the Community College*, *19*(2), 3-11.

Koenker, R. (2018). quantreg: Quantile Regression. R package version 5.38. Available at: https://CRAN.R-project.org/package=quantreg

Koenker, R. (2000). Galton, Edgeworth, Frisch, and prospects for quantile regression in econometrics. *Journal of Econometrics*, *95*(2), 347-374.

Krause, K-L. (2005). Serious thoughts about dropping out in first year: Trends, patterns and implications for higher education. *Studies in Learning, Evaluation Innovation and Development, 2*(3), 55-68. Retrieved from http://sleid.cqu.edu.au/viewarticle.php?id=84

Laursen, S. L., Hassi, M. L., Kogan, M., & Weston, T. J. (2014). Benefits for women and men of inquiry-based learning in college mathematics: A multi-institution study. *Journal for Research in Mathematics Education*, *45*(4), 406-418.

Ma, X. J., & He, F. X. (2014). Power weighted quantile regression and its application. *Journal of Data Science*, *12*(3), 535-544.

 

Møller, J. K., Nielsen, H. A., & Madsen, H. (2008). Time-adaptive quantile regression. *Computational Statistics & Data Analysis*, *52*(3), 1292-1303.

Moore, M. G. (2013). The theory of transactional distance. In M. G. Moore (Ed.), Handbook of distance education (3rd ed.). New York, NY: Routledge.

Olson, S., & Riordan, D. G. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*.

Portnoy, S., & Koenker, R. (1997). The Gaussian hare and the Laplacian tortoise: computability of squared-error versus absolute-error estimators. *Statistical Science*, *12*(4), 279-300.

Rasmussen, C., Apkarian, N., Bressoud, D., Ellis, J., Johnson, E., & Larsen, S. (2016). A national investigation of Precalculus through Calculus 2. In *Proceedings of the 19th Annual Conference on Research in Undergraduate Mathematics Education* (pp. 1245-1251).

Talbot, R. M., Hartley, L. M., Marzetta, K., & Wee, B. S. (2015). Transforming undergraduate science education with learning assistants: student satisfaction in large-enrollment courses. *J College Sci Teach, 44*(5), 24–30.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Grummer, J. A. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476-6483.

Thomas, L., Herbert, J., & Teras, M. (2014). A sense of belonging to enhance, participation, success and retention in online programs. *The International Journal of the First Year in Higher Education, 5*(2), 69–80.

Tinto, V. 2004. Linking learning and leaving. In J. M. Braxton (Ed.) *Reworking the Student Departure Puzzle*, pp. 81–94. Nashville, TN: Vanderbilt University Press.

Webb, D. C., Stade, E., & Grover, R. (2014). Rousing students' minds in postsecondary mathematics: the undergraduate learning assistant model. J Math Educ Teach College, 5(2)).

Xiong, W., & Tian, M. (2019). Weighted quantile regression theory and its application. *Journal of Data Science*, *17*(1), 145-160.

Xu, D., & Jaggars, S. S. (2014). Performance gaps between online and face-to-face courses: Differences across types of students and academic subject areas. *The Journal of Higher Education*, *85*(5), 633-659.

Zhang, L., Wang, H. J., & Zhu, Z. (2017). Composite change point estimation for bent line quantile regression. *Annals of the Institute of Statistical Mathematics*, *69*(1), 145-168.

Zhou, K. Q., & Portnoy, S. L. (1998). Statistical inference on heteroscedastic models based on regression quantiles. *Journal of Nonparametric Statistics*, *9*(3), 239-260.

 