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Project-Based Statistics Outcomes Pre- and Post-COVID

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ABSTRACT

The COVID-19 pandemic altered course delivery in higher education at many universities. This article evaluates the differences between student experiences in the fall 2019 semester (pre-pandemic) and those during the fall 2020 semester (pandemic) within a multidisciplinary, project-based introductory statistics course. Results indicated that there were minimal differences in student experiences of this course based on delivery mode (in person vs. online).

KEYWORDS

Statistics education research; Passion-driven statistics; Applied data analysis; Project-based introductory statistics

Due to the COVID-19 pandemic, many courses that would ordinarily have been held in person were suddenly changed to an online format for emergency distance learning. Research in higher education has looked at many of the initial obstacles for teaching and learning in a socially distanced, online environment, identifying core issues surrounding access to technology (Mahyoob, 2020; Rajab et al., 2020) and faculty's preparedness to shift to online platforms (Gathings, 2022; Mahwish et al., 2020; Valsaraj et al., 2021), as well as challenges for maintaining student satisfaction and engagement (Baber, 2020; Coman et al., 2020; Mahyoob, 2020; Murphy et al., 2020). Lack of student-to-teacher and student-to-peer interaction, impaired sense of affiliation (or belonging), increased environmental distractions and stressors, and limited digital proficiency have all been identified as factors that affected student engagement and satisfaction during the pandemic (Deng & Yang, 2021; Igai & Yunus, 2022; Kofoed et al., 2021; Morris et al., 2021; Pennino et al., 2022).

Additional studies have attempted to understand the impact of the pandemic on specific subpopulations and have identified a diverse range of experiences based on home environment, income level, race, gender, and first-generation status, suggesting that there is no one dominant experience, but rather that college students had a variety of experiences during the pandemic (Barber et al., 2021; Kiebler & Stewart, 2022; Morris et al., 2021; Tate & Warschauer, 2022; Walsh et al., 2021).

Beyond these findings, few studies have directly compared differences in course-specific outcomes from pandemic (in-person courses) to pre-pandemic (online courses) times. Orlov and colleagues (2021) and Kofoed and colleagues (2021) found a small but significant negative impact of pandemic distance learning on student performance and learning outcomes. Likewise, only two studies, to the best of our knowledge, have discussed the implementation of project-based learning in research-focused curriculums in the COVID-19 remote-learning environment. Both researchers found benefits of project-based learning in terms of engagement and increased interest in conducting research in the future (Barber et al., 2021; Randazzo et al., 2021).

The Passion-Driven Statistics course is uniquely positioned to offer insight into changes in enrollment composition, student outcomes, behaviors, and attitudes between the pandemic and pre-pandemic semesters because these data were already being collected across universities prior to the pandemic. The aim of our study is to investigate these differences in the PDS course and to assess the adaptiveness of the curriculum in the face of emergency online learning.

History of Passion-Driven Statistics

Passion-Driven Statistics (PDS) is a multidisciplinary, project-based introductory statistics course that was

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developed to engage students in a semester-long project of their choosing to give them an authentic undergraduate research experience (Dierker et al., 2012). The rationale behind this approach is to leverage the benefits of inquiry-based learning (Bailey et al., 2013) and flipped classrooms (Carlson & Winquist, 2011; Heringer et al., 2019; Khan & Watson, 2018; Nielson et al., 2018; Wilson, 2013; Winquist & Carlson, 2014) to promote deep statistical thinking (da Silva & Pinto, 2014). The PDS model provides an opportunity to teach an introductory course that engages students who have varying levels of preparation (Hatfull et al., 2006; Jones et al., 1997; Mergendoller et al., 2006).

This model is used by a variety of higher education institutions (including liberal arts colleges, large state universities, regional colleges and universities, and community colleges), as well as secondary institutions. The model was used in statistics, research methods, and data science courses, with students from a wide variety of academic disciplines.

Previous research on this inquiry-based course has revealed that PDS has successfully attracted a more diverse set of students both in terms of mathematical aptitude (as measured by math SAT scores) and background characteristics (such as race and gender) than have traditional introductory statistics and computer science programming courses (Cooper & Dierker, 2016; Dierker et al., 2015). In addition, PDS has shown increased reported interest from students in pursuing advanced coursework in statistics compared with students in a math statistics course (Dierker et al., 2018), as well as increases in future course enrollment in data science and statistics courses compared with both math statistics and psychology statistics courses (Nazzaro et al., 2020).

Changes in Delivery Pre-Pandemic to Pandemic

In fall 2019 (pre-pandemic), students engaged asynchronously with videos that introduced statistical concepts and programming across several statistical software platforms (e.g., R, SAS, Python, Stata, or SPSS). During the synchronous portion of the class, students worked in groups and in one-on-one interactions with their instructors and teaching assistants to work through their project.

In fall 2020 (pandemic), the course transitioned to fully online across the institutions participating in this study. The only structural change was that the synchronous portions of class were held online (via Zoom, Microsoft Teams, or Google Classroom, depending on the institution). As before, students worked in groups and received one-on-one support for their projects.

Research Questions

The purpose of this study is to determine whether there were any differences between student enrollment and student experiences with the course during the pandemic compared with pre-pandemic. The study examines (i) precourse differences in enrollment; (ii) postcourse differences in perceived gains, classroom behaviors, perceived value of course, and intended future use of the course material; and (iii) whether course delivery and the pandemic affected some student populations more than others in terms of their experience with the curriculum.

Methods

Participants

Pre- and postcourse survey data were drawn from 894 students at 28 postsecondary institutions in the United States enrolled in the project-based statistics course in fall 2019 (pre-pandemic) and fall 2020 (during the pandemic). Of these surveys, 494 came from students enrolled in the in-person course in fall 2019, and 400 came from students enrolled in online offerings in fall 2020.

Measures

Data were drawn from both a precourse survey completed by the end of the second week of classes and a postcourse survey completed during the last week of the course. Each survey took approximately 10 to 15 minutes to complete.

Institution Type

Institution types represented in the data included private liberal arts colleges or universities, large state universities, regional colleges or universities, and community colleges.

Background Characteristics

Students self-reported their gender and race or ethnicity. Two binary variables were created for students with Hispanic ethnicity and Black students. Additionally, students self-reported whether or not they were a first-generation student and whether they were eligible to receive free or reduced lunch in high school. Class year was dichotomized into first- and

second-year students compared with third- and fourth-year students.

Academic background in the precourse survey was dichotomously coded with whether the student had prior experience in statistics or programming.

Precourse Attitudes

An item from the Attitudes Toward Statistics Scale (Wise, 1985) was used to measure students' agreement with respect to how nervous they were at the thought of being enrolled in a statistics course, on a scale of 1 (strongly disagree) to 5 (strongly agree).

Students' self-confidence was assessed by their responses, on a scale from 1 (strongly disagree) to 5 (strongly agree), to the following statement: "I have a lot of self-confidence when it comes to learning programming." This item was drawn from the Adapted Computer Science Attitude Survey (Wiebe et al., 2003).

Postcourse Attitudes and Outcomes

The Undergraduate Research Student Self-Assessment (URSSA) was used to measure students' self-reported gains in thinking and working like a scientist, personal gains related to research, gains in research skills, and attitudes and behaviors.

Previous research has shown that the URSSA represents separate but related constructs for cognitive skills and affective learning gains from the undergraduate research experience. Average scores formed reliable moderate to highly correlated composite measures. Student learning gains have been shown to correlate with ratings of satisfaction with external aspects of the research experience (Weston & Laursen, 2015). Average scores across each construct were calculated when responses to at least 50% of the corresponding survey items were available.

Classroom behaviors were assessed with four questions on the postcourse survey. On a scale of 1 (never) to 5 (very often), students rated the extent to which they asked questions in class, came to the class session prepared (i.e., by completing the assigned readings and/or videos), worked with other students from class, and participated in classroom discussions.

The perceived value of the course was assessed with four separate questions on the postcourse survey. On a scale from 1 (never) to 5 (always), students rated the extent to which they felt excited to learn new concepts in the course. On a scale from 1 (not at all rewarding) to 5 (extremely rewarding), students rated how rewarding they found the course. On a scale from 1 (not at all likely) to 5 (extremely likely), students rated how likely they are to use the skills they learned in the course. On a scale from 1 (definitely not) to 5 (definitely yes), students rated whether they intended to take any statistics or data analysis courses in the future.

Analysis

We conducted bivariate analyses to examine differences between students enrolling in the course prior to the pandemic and during the pandemic in terms of background characteristics, course experiences, and course outcomes. We used chi-square tests of independence and analyses of variance (ANOVA) for categorical and quantitative variables, respectively. We used multilevel modeling using complete case analysis to evaluate differences in postcourse gains between students enrolled pre-pandemic (fall 2019) and during the pandemic (fall 2020), adjusting for student characteristics. The multilevel model allowed us to estimate differences in gains between students while adjusting for clustering of students within institutions. We ran a separate multilevel model on each outcome and student experience under investigation (12 models total). Each model tested the significance of pandemic enrollment, adjusting for student background characteristics, precourse attitudes, and institution type.

Additionally, to test whether the mode of delivery and the pandemic impacted historically underrepresented students differently, we tested 60 two-way interactions between semester (pandemic vs. pre-pandemic) with gender, first-generation status, recipients of free lunch in high school, and the indicators for Hispanic and Black students.

Results

Student Characteristics by Semester

Table 1 shows the differences between the background characteristics collected at the beginning of the semester in the pre-pandemic course (fall 2019) and during the pandemic (fall 2020).

The course attracted similar rates of students across the demographics investigated for both the pre-pandemic and pandemic semesters. Both self-confidence and prior experience with coding also did not vary significantly between semesters. The only statistically significant difference found was that students were more nervous taking a project-based statistics course during the pandemic semester than they were during the pre-pandemic semester.

Table 1. Demographic and precourse attitude differences.

	Pre-pandemic ($n = 494$)	Pandemic ($n = 400$)	Test statistic (p value)
Female	291 (61.7%)	244 (65.8%)	$\chi^2(1) = 1.35$, $p = 0.246$
First generation	110 (23.4%)	87 (23.4%)	$\chi2(1) = 0.00$, $p = 1.00$
Free lunch	102 (21.6%)	100 (27.0%)	$\chi2(1) = 3.05$, $p = 0.081$
Black	47 (9.5%)	37 (9.2%)	$\chi2(1) = 0.00$, $p = 0.985$
Hispanic	84 (17.0%)	64 (16.0%)	$\chi2(1) = 0.10$, $p = 0.756$
Freshman or sophomore	201 (40.7%)	149 (37.2%)	$\chi2(1) = 0.957$, $p = 0.328$
Self-confidence to learn programming	2.7 (± 1.0)	2.6 (± 1.0)	$F(1, 845) = 2.78$, $p = 0.096$
Prior experience	149 (31.4%)	105 (27.9%)	$\chi2(1) = 1.07$, $p = 0.301$
Nervous	3.1 (± 1.2)	3.4 (± 1.2)	$F(1, 848) = 11.2$, $p = 0.001$

Note. Sample sizes varied from 842 to 894 due to missing values. Mean (SD) reported for quantitative variables.

Table 2. Estimated main effect of the pandemic on outcomes.

	Adjusted differences (pandemic vs. pre-pandemic)
Gains	
Attitudes and behaviors	−0.012 (-0.167, 0.143)
Personal gains	−0.066 (-0.220, 0.087)
Skills	−0.085 (-0.229, 0.059)
Thinking like a scientist	−0.061 (-0.181, 0.059)
Classroom behaviors	
Asks questions in class	−0.1636** (-0.322, -0.005)
Prepared for class	0.098 (-0.056, 0.253)
Studies with others	−0.382*** (-0.599, -0.165)
Participation	−0.246 (-0.728, 0.236)
Value of course	
Excited to learn more	−0.108 (-0.270, 0.054)
Found class rewarding	−0.083 (-0.233, 0.066)
Use skills in future	−0.12 (-0.282, 0.041)
Interest to take future statistics courses	−0.112 (-0.266, 0.043)

Multilevel Modeling of Course Experiences and Outcomes by Semester

Table 2 shows the multilevel model results for the main effect of the pandemic on each of the 12 outcomes, adjusting for student background characteristics, precourse attitudes, and institution type.

Despite the average of all URSSA postcourse gains composite scores being slightly lower during the pandemic semester than they were for the pre-pandemic semester, the adjusted models revealed no significant differences between the semesters in students' postcourse research gains, as indicated by the 95% confidence intervals.

Some classroom behaviors did vary significantly between semesters. In particular, students who took the course during the pandemic reported asking questions significantly less often than did students who took the course pre-pandemic.

In addition, students who took the course during the pandemic reported studying with others significantly less often compared than students who took the course pre-pandemic. Although students reported being more prepared for class during the pandemic, the difference was not deemed significant. In addition, even though students reported participating less frequently during the pandemic, that difference was also not significant.

Measures for the perceived value of the course and the intended future use of statistics (although slightly lower during the pandemic than pre-pandemic) did not vary significantly between semesters.

Follow-up analyses testing for interactions with demographic characteristics revealed that the main effects reported in Table 2 for frequency of asking questions and participation are qualified by statistically significant interactions. Plots for the significant interactions are shown in Figure 1. There were significant gender and Hispanic ethnicity interactions for differences between semesters in frequency of asking questions ($B = 0.34$, 95% CI = [0.05, 0.64] and $B = 0.43$, 95% CI = [0.06, 0.80], for gender and Hispanic ethnicity, respectively). For female students, there was little difference in the frequency of asking questions between the pre-pandemic and pandemic semesters. On the other hand, non-female students showed a significant decrease in the frequency of asking questions. Hispanic students showed an increase in the frequency of asking questions between the pre-pandemic and pandemic semesters, whereas the frequency of asking questions decreased for non-Hispanic students. Similarly, Hispanic students showed an increase in frequency of participation between the pre-pandemic and pandemic semesters, whereas the frequency of participation decreased for non-Hispanic students ($B = 0.41$, 95% CI = [0.00,

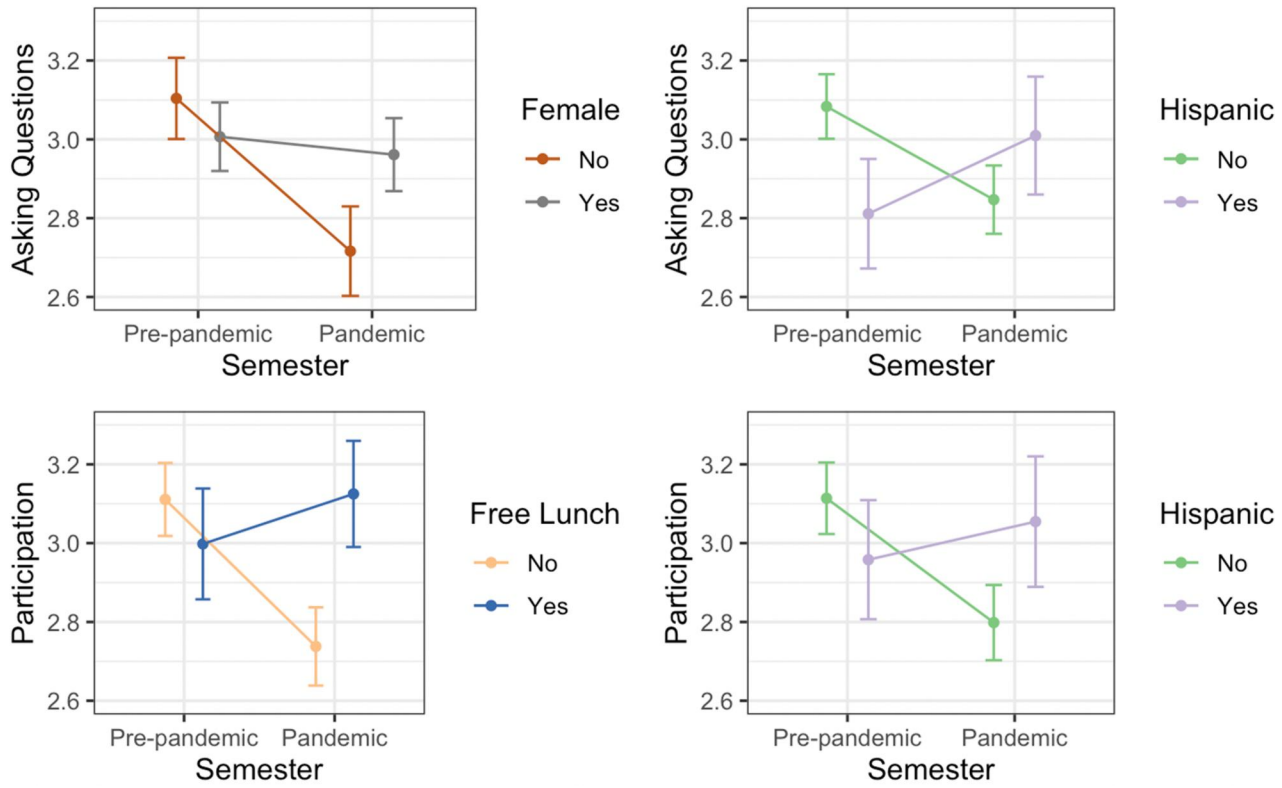

Figure 1. Interaction plots.
Note. Students were asked whether they identified as female (yes or no), so "no" does not necessarily mean they identified as male, just that they did not identify as female.

0.81]). Finally, students who reported having free lunch in high school showed an increase in frequency of participation between the pre-pandemic and pandemic semesters, whereas the frequency of participation decreased for students who did not receive free lunch in high school ($B = 0.50$, 95% CI = [0.14, 0.86]).

Discussion

Students' perceptions and satisfaction in courses are important areas of study in education because they relate to students' academic performance (Dhaqane & Afrah, 2016), as well as retention and continued effort in learning (He et al., 2014). Some studies have shown similar levels of satisfaction between students in online courses and those taking in-person courses (Garratt-Reed et al., 2016; Yen et al., 2018), whereas others have shown that students are more satisfied with in-person courses than online courses (Dinh & Nguyen, 2020; Tratnik et al., 2019). The results of this study found no significant differences in perceived research gains between the pandemic and pre-pandemic semesters, nor was there evidence of a differential impact on research gains, value of course, and intended future use due to the course delivery or the pandemic for female students, students from underrepresented groups, first-generation students, and students who received free lunch in high school.

Not surprisingly, students in this study asked fewer questions and studied with others less often during the pandemic, a logical symptom of learning in a socially distanced environment. This finding is supported by research that shows students felt disconnected during the pandemic (Kofoed et al., 2021; Selco & Habbak, 2021). Although there is a belief that the pandemic widened the gap in learning outcomes for students from racial and ethnic minority backgrounds and students from families with lower incomes (Tate & Warschauer, 2022), it is possible that the increased level of participation by Hispanic students and students from families with lower incomes found in our study offset other challenges faced by these groups, allowing for no meaningful differences noted in learning gains. Additionally, our findings that non-female students asked fewer questions during the pandemic but female students had no notable change is possibly related to noted differences in self-regulated learning skills during the emergency shift to online learning (Kofoed et al., 2021; Liu et al., 2021; Schwam et al., 2021).

Researchers have shown that pre-pandemic online courses had notable benefits of convenience, accessibility, and autonomy of learning (Northrup, 2009). In practice, this finding is important because such an environment can attract a more diverse set of learners who have work-life commitments outside of their education. Furthermore, previous research on student satisfaction with online learning has emphasized the importance of students having an active learning environment and frequent and consistent interaction with their instructors and other students (Young & Norgard, 2006). Studies have shown that including both synchronous and asynchronous components contributes to online learning satisfaction (Amir et al., 2020). Initial research on student satisfaction in higher education at early stages of the pandemic has suggested that instructors should focus on attitude development (Afreen & Chaubey, 2020) and foster social interaction and learner-content interaction in online learning. Taken together, the findings from this study suggest that the PDS course format reaps similar benefits in its online adaptation and may be beneficial in the future for reaching more students who could benefit from statistical thinking and data-driven work.

The economic and health shocks of the pandemic varied depending on one's socioeconomic status and caused a disproportionate percentage of students from families with lower incomes to delay graduation (Aucejo et al., 2020). Therefore, one might have expected that courses during the pandemic would have served a smaller percentage of students from underrepresented groups compared with pre-pandemic semesters. However, we did not find any notable differences in the student demographic composition between the two semesters for this project-based statistics course. More work would need to be done to investigate whether this finding can be attributed to any features of the course that made it less susceptible to drop-off from students from underrepresented groups during the pandemic.

There were some limitations to this study. In addition to the limitation due to the nature of the observational data coming from a self-report survey, response rates varied across institutions, and the potential for nonresponse bias implies we cannot generalize to the entire college student population. We also recognize that the effects of intersectionality among background characteristics—namely, first generation or free lunch and ethnicity—on outcome measures were not investigated. More work is needed to understand these potential impacts.

Although our study did not find evidence of a change in perceived gains as a result of the course delivery mode or the pandemic, replication of the study will be critical to increase confidence that the PDS model is impervious to mode of course delivery. The pandemic provided a natural opportunity to compare online and in-person delivery modes, but as with all naturally occurring field studies, other factors and outcomes not examined in this study could reveal differences between modes of delivery.

Conclusion

Given that we have previously shown that the project-based curriculum attracts higher rates of students from underrepresented groups compared with a traditional math statistics curriculum (Dierker et al., 2015; Dierker et al., 2012) and that it is successful in influencing future course choices (Nazzaro et al., 2020), the results of this study can be interpreted as particularly promising. Overall, students experienced a smooth transition from in-person to fully online courses with few disruptions, and their self-reported gains remained strong.

We believe that this multidisciplinary, project-based model can benefit other schools, and we are currently disseminating it across diverse educational settings. We are happy to share our course materials with others and encourage instructors to consider using a multidisciplinary, project-based approach for their in-person and virtual classrooms. (Learn more at http://passiondrivenstatistics.com/.)

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