

Academic Outcomes and Experiences of Freshman Students in Mathematics Courses During the COVID-19 Pandemic

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Abstract

This article reports on a study of academic experiences and outcomes for a sample of 1,346 freshman students who completed a virtually taught first-year mathematics course during the fall 2020 semester. Overall student achievement during the fall 2020 semester, during which courses were taught in a virtual modality, remained at the same level as the previous five fall semesters in which courses were taught in a traditional face-to-face modality. While approximately 66% of students preferred face-to-face courses over virtually taught courses, 18% indicated a preference for virtual courses. Overall, this study found evidence that offering both face-to-face and virtual first-year mathematics courses may be a viable and sustainable option going forward.

Keywords. Freshman, mathematics, COVID-19, achievement, equity

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Introduction

Over the past 20 years, distance or online education has become increasingly common. However, fully online course offerings in mathematics for introductory coursework at the college and university level have remained limited (Shalby, 2021). While some institutions have offered a few sections of a course offered in an online or hybrid modality, the vast majority of course offerings were fully face-to-face. Hybrid or flipped modality classes, while focusing on student-centered learning activities, often did not decrease the amount of face-to-face contact time (e.g., Cronjort et al., 2020). These practices have been shown to increase student persistence and achievement in mathematics coursework, especially for students from underrepresented backgrounds (Freeman et al., 2014). For fully online education to work well on a large scale, the American Mathematical Association of Two-Year Colleges has said that instructor training in online pedagogy, tools, and practices is necessary, together with institutional commitment to support faculty to acquire these skills (Blair, 2006). These and other factors may have contributed to hesitancy to adopt online modality mathematics courses on a large scale. In addition, most students who enrolled in a virtual rather than a face-to-face mathematics course did so by choice (Comas-Quinn, 2011).

On March 11, 2020, the World Health Organization declared COVID-19 as a global pandemic (Branswell & Joseph, 2020). As a result, virtually every student was suddenly taking her or his courses in a virtual modality. The real-time nature of this shift produced a unique moment in education. By Fall 2020, colleges and universities were able to plan on offering most of their courses in a virtual modality.

Our study focuses on the experiences and academic outcomes of freshman students enrolled in fully virtual mathematics courses during the pandemic. To distinguish this situation from online teaching and learning pre-pandemic, we refer throughout this paper to “virtual teaching” (VT). In this context, VT refers to fully synchronous (real-time) online instruction via Zoom, as compared to traditional face-to-face (FF) courses. Our goal was twofold: first, to document freshman students’ experience and academic outcomes during a truly unique moment in history; and second, to investigate the implications of this experience and how we may effectively adjust course offerings and choices for students as we navigate “the new normal.” Specifically, we investigated the following research questions:

RQ1. How did academic outcomes for freshman students taking virtual courses compare with freshman students from previous semesters taking face-to-face courses?

RQ2. What factors influenced freshman students' preferences for taking virtual or face-to-face courses?

In this sense, the present study is essentially a large-scale program evaluation that may be helpful in informing mathematics programs at both two-year and four-year institutions considering offering more virtual mathematics courses as we move into a post-pandemic era.

Review of Literature

There is rich historical literature describing and documenting the impact of the student experience in college, both academically and socially. Dr. Alexander Astin, founding director of the Higher Education Research Institute (2021), documented the performance, experience, and attitudes of undergraduate students at colleges and universities across the nation for more than 50 years. Pascarella and Terenzini (1991) described the profound impact that the college experience can have, both positively and negatively, upon the lives of young adults. Astin (1993) and Tinto (1994) each identified factors underlying student attrition and what colleges and universities can do to reduce it. Tinto's celebrated model for student retention centers around building inclusive educational and social student communities. Nearly 20 years later, Tinto (2012) revisited these themes from the perspective of why some students complete college, why some do not, and how institutions can meaningfully support student success for an increasingly diverse population.

Each of these studies identified the student's first year in college as often being the most critical.

Bailey et al. (2015) applied this framework to the specific needs of community colleges and their students. Drew (1996, 2011) described institutions and programs that successfully supported the work of students in the disciplines of science, technology, engineering, and mathematics and how institutions and departments can adapt and implement effective programs. Key factors for students, especially those from traditionally underrepresented groups, included academic support, financial assistance, and professional opportunities. Central to this research is the overarching construct that what institutional leaders and educators do and believe matters deeply. Moreover, what happens during the student's first year in college can have a lasting impact on her or his subsequent academic trajectory and professional choices.

Research regarding pre-pandemic online instruction helps to provide an important context for this study. Anderson (2011) created a theoretical model which posits four overlapping dimensions for learning. These dimensions include learner-centered, knowledge-centered, assessment-centered, and community-centered. Within the context of online learning specifically, Anderson defined and valued interaction in online learning as a key component of adapting in-person pedagogical practices to a virtual setting. However, virtual instruction can also

be impacted by limitations of technology performance and access (Comas-Quinn, 2011).

Recent studies have explored the impact of the college student experience in a virtual setting. As part of a recently funded National Science Foundation study, McCormick (2020) stated, “The impacts of this unexpected transition to distance learning are not equal among students. As universities closed, many students entered resource-limited or stressful domestic situations that are not conducive to learning” (p. 1). Cao et al. (2020), based on a large sample of undergraduate pre-medical students enrolled at universities in China, found that about one-fourth of the students reported mild to high levels of anxiety associated with the pandemic. Specifically identified factors included increased economic challenges, decreased social support, and having a family member who was COVID-19 positive. The authors conclude that “the mental health of college students should be monitored during epidemics” (p. 1). Browning et al. (2021) reported similar findings for a sample of college students taken across seven U.S. states. Copeland et al. (2021) reported on the impact of COVID-19 on college student mental health and wellness, specifically among college freshmen. The authors of the study collected data on approximately 500 college freshmen completing pre- and post-semester assessments as well as nightly surveys of mood and wellness behaviors. The authors concluded that university efforts to

help students cope during the semester had a “modest but persistent impact” on students’ mood and wellness behaviors (p. 134). A recent study in Austria and Finland examined psychological characteristics associated with university students’ well-being during the pandemic. The results indicated that competence predicted positive emotion in university students during the pandemic and that autonomy and self-regulated learning contributed to intrinsic learning motivation (Holzer et al., 2021).

Much of the current research on the impact of COVID-19 has centered around factors related to students’ mental and emotional experiences (e.g., Tonon, 2020). Informed by this work, the current study seeks to extend this research to examine the academic experiences and mathematics course outcomes during the pandemic for freshman students.

Methodology

Context and Survey

The California State University (CSU) is the largest public state university system in the U.S. In fall 2020, more than 480,000 students were enrolled in one of 23 campuses. The CSU is one of the most ethnically and racially diverse university systems in the U.S. One-third of its undergraduates are the first persons in their families to attend college (CSU, 2020). The current study took place at California State University, Fullerton (CSUF), one of the largest universities in the CSU, with more than 41,000 students enrolled in

fall 2020. CSUF is a designated Hispanic Serving Institution and an Asian American and Pacific Islander Serving Institution. CSUF is largely a commuter campus, with about 2% of students living in on-campus or university-sponsored housing (U.S. News, 2021). The mathematics department at CSUF enrolls some 15,000 students each year and employs about 90 faculty, including full-time and adjunct instructors.

A 33-item survey was given to freshman students enrolled in one or more mathematics courses in fall 2020 at CSUF. The survey was divided into eight blocks of questions asking about their experiences in taking online or virtual teaching (VT) classes in fall 2020 as compared with teaching traditional face-to-face (FF) classes in fall 2019 (Appendix 1). The survey was based in large part on surveys used in two major studies, including an NSF-funded research study (Network for Research and Evaluation, 2020) and research conducted by the Conference Board of the Mathematical Sciences (CBMS, 2020). These studies explored the effects COVID-19 had on students' personal lives, academic work, and mental health and the impact on mathematics departments of pivoting from face-to-face to virtual classes.

Sample

The survey was given to freshman students enrolled in a mathematics course during weeks 10 and 11 of the 15-week fall 2020 semester. The survey was given online using Qualtrics software and

took about ten minutes to complete. All mathematics courses were taught in a synchronous (real-time) environment. CSUF Institutional Review Board protocols were closely observed, and all student responses were analyzed and reported in aggregate form. All statistical analyses were done using SPSS, Version 27; missing data were handled using pairwise exclusion. Student course outcome data for each survey participant, including course grade and success or non-success in the course, were taken directly from institutional records and linked to that student's survey response in the data set.

The sample group for this study included students who (1) were enrolled in a mathematics course at CSUF in fall 2020 and completed the survey; (2) self-identified as freshmen on the survey; (3) self-identified their gender as either male or female; and (4) self-identified their ethnicity from one of these categories: African-American/Black, Asian/Asian-American, Hispanic/Latinx, Native American/Indigenous, Pacific Islander, or white/non-Hispanic. A total of 1346 students met all four criteria and were included in the sample (Table 1). Nearly every student (99.1%) self-identified her or his age group as 18-19 years. Four-fifths of the students (80.5%) identified their previous (spring 2020 semester) institution as high school, and 18.4% were previously enrolled at CSUF. Per CSU protocol, students self-identifying as African American/Black, Hispanic/Latinx, Native American/Indigenous, or Pacific Islander

were classified as being from underrepresented minority groups (URM). Students self-identifying as white/non-Hispanic or Asian/Asian-American were classified as being from non-underrepresented minority groups (non-URM). Sixty percent of the respondents self-identified as URM students, and 61.8% as female. Female URM students comprised the largest of the four gender/URM groups (URM males, URM females, non-URM males, and non-URM females) with 525 (39.0%) members. Hispanic/Latinx students comprised 93.9% of the URM group, and Asian/Asian-American students comprised 70.0% of the non-URM group. Three-fifths (60.6%) of the students indicated that they were the first in their families to attend college, and 72.3% indicated that they were receiving financial aid (Table 2).

Table 1
Number (percentage) of freshman students by gender and ethnicity

	African- Amer/Black	Asian/ Asian-Amer	Hispanic/ Latinx	Nat Amer/ Indigenous	Pacific Islander	White/ non-Hisp	Total
Male	11 (0.8)	168 (12.5)	267 (19.8)	0 (0.0)	6 (0.4)	62 (4.6)	514 (38.2)
Female	23 (1.7)	208 (15.5)	493 (36.6)	0 (0.0)	9 (0.7)	99 (7.4)	832 (61.8)
Total	34 (2.5)	376 (27.9)	760 (56.6)	0 (0.0)	15 (1.1)	161 (12.0)	1346 (100.0)

Table 2
Number (percentage) of freshman students by background characteristics

	URM	Non-URM	First in family to attend college	Receiving financial aid	Total
Male	284 (55.3)	230 (44.7)	288 (56.1)	351 (68.3)	514 (38.2)
Female	525 (63.1)	307 (36.9)	527 (63.4)	622 (74.8)	832 (61.8)
Total	809 (60.1)	537 (39.9)	815 (60.6)	973 (72.3)	1346 (100.0)

Results

Course Outcomes

Freshman students typically enroll in one of seven courses during their first year at CSUF, including liberal arts math, introductory statistics, college algebra, precalculus, calculus for the life sciences, business calculus, or first-semester calculus. These courses meet the university general education (GE) quantitative reasoning requirement. At CSUF, a successful grade outcome is defined as having completed the course with a final grade of C or better (per university policy, a grade of C- is considered successful for liberal arts math); any other grade outcome including withdrawing from the course is considered non-successful. All multi-section mathematics courses at CSUF follow common course guidelines, including weightings for exams/assessments, homework assignments, etc., as well as common grading scales. During the fall 2020 semester, exams/assessments were given in a synchronous timed setting with students being required to have their video cameras on throughout the exams.

Aggregate and Subgroup Outcomes

Using a standard 4-point grading scale, the average (mean) grade for freshman students in the fall 2020 sample was 2.57, and the success rate was 81.6% (Table 3). Controlling for gender showed that female students had statistically significantly higher course outcome measures than did males for both average course grade ($t =$

-3.744, $p < .001$, $df = 1032$) and course success rate ($t = -2.994$, $p < .003$, $df = 977$) based on the data in Table 4. Similarly, controlling for URM status showed that non-URM students had significantly higher course outcome measures than did URM students for both average course grade ($t = -7.253$, $p < .001$, $df = 1344$) and course success rate ($t = -4.355$, $p < .001$, $df = 1290$). Moreover, disaggregating course outcomes by both gender and URM status revealed statistically significant differences between the four gender/URM subgroups for both average course grade and course success rates using ANOVA (Table 5). Average course grades in the fall 2020 sample for the four subgroups were, in decreasing order, non-URM females (3.01), non-URM males (2.63), URM females (2.46), and URM males (2.24). Course success rates for the same four subgroups were 90.2%, 82.6%, 80.6%, and 73.2%, respectively.

Table 3
Average course grade and success rates for freshman students

	Average course grade			Course success rate	
	<i>N</i>	\bar{x}	<i>S_x</i>	\hat{p}	<i>S_x</i>
Male	514	2.42	1.218	.774	.418
Female	832	2.67	1.139	.841	.366
Total	1346	2.57	1.176	.816	.388

Table 4
Average course grade and success rates By gender and URM status

	Average course grade		Course success rate	
	URM	non-URM	URM	non-URM
Male	2.24	2.63	.732	.826
Female	2.46	3.01	.806	.902
Total	2.39	2.85	.780	.870

Table 5*Analysis of variance of course outcomes for freshman students*

Course Grade		sum of squares	df	mean square	F	Significance
Gender status	Between groups	7.438	11	.676	2.907	.001*
	Within groups	310.279	1334	.233		
	Total	317.718	1345			
URM status	Between groups	19.415	11	1.765	7.762	< .001**
	Within groups	303.344	1334	.227		
	Total	322.769	1345			
Course Success Rate						
Gender status	Between groups	2.242	1	2.242	9.550	.002*
	Within groups	315.476	1334	.235		
	Total	317.718	1345			
URM status	Between groups	4.140	1	4.140	17.465	< .001**
	Within groups	318.618	1334	.237		
	Total	322.759	1345			

Gender/URM Status Subgroups

While differences between the four gender/URM status subgroups were noted in the fall 2020 virtual instruction sample, we wondered how these differences from the fall 2019 face-to-face instruction semester compared with differences during the fall 2020 online semester. Based on institutional records, we compared outcomes for the same four subgroups of all freshman students enrolled in a GE mathematics course in fall 2019 ($n = 3285$) with those in fall 2020 ($n = 3980$). No significant differences between the fall 2019 and fall 2020 groups were observed for the subgroups of URM males, non-URM males, and URM females for both average course grade and course success rate. Significant differences at the .05 level were observed for non-URM females for an average course grade of .30 (95% CI = [.18, .42]) grade points and course success rate

of 5.8 [1.9, 9.7] percentage points, both favoring the fall 2020 virtual semester.

Table 6

Course outcomes for all freshman students enrolled in GE math Fall 2019 and Fall 2020

		Fall 2019		Fall 2020		Difference	
		URM	non-URM	URM	non-URM	URM	non-URM
Average Course Grade	Male	2.00	2.38	2.07	2.49	.07	.11
	Female	2.24	2.61	2.28	2.91	.04	.30 ⁺
Course Success Rate	Male	.654	.755	.656	.784	.002	.029
	Female	.717	.817	.727	.875	.010	.058 ⁺

⁺*p* < .05

Previous Years

Freshmen student course outcome data taken from CSUF institutional records provided a basis for comparison of overall student achievement in GE mathematics courses in fall 2020 compared to that during the previous five fall semesters. Other than a few experimental online-only sections of large multi-section courses, all courses from fall 2015 through fall 2019 were taught in traditional face-to-face formats. All classes in fall 2020 were taught in a virtual format. Average course grades and success rates each semester among freshman students enrolled in GE mathematics courses during this period ranged from 2.12 to 2.42 and from 70.7% to 77.3%, respectively. Course outcomes for the fall 2020 semester compared favorably with those from the previous five years, ranking first for average course grade and second for course success rate. Overall, freshmen student enrollment in these courses in fall

2020 ($n = 3849$) was the highest during the six-semester period (average enrollment = 3110). Moreover, trend lines for each set of course outcome measures indicate a slightly positive rate of change during this time period (Figures 1 and 2).

Figure 1

Average GE mathematics course grade for freshman students, Fall 2015 - Fall 2020

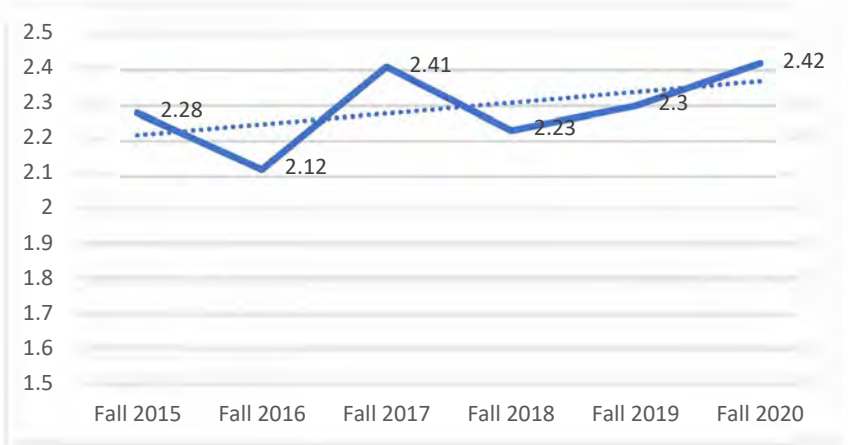
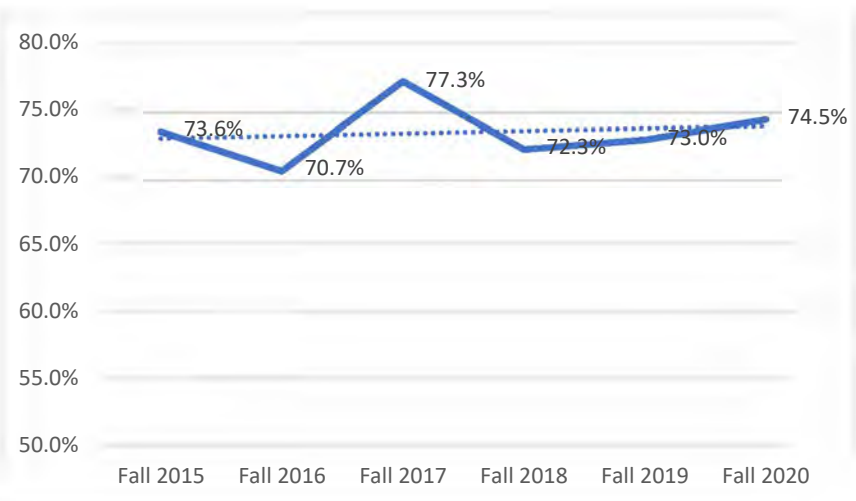


Figure 2

GE mathematics course success rates for freshman students, Fall 2015 - Fall 2020



Standardized Courses

While all multi-section mathematics courses at CSUF follow common course guidelines, the two mathematics courses at CSUF with the greatest enrollments, college algebra, and precalculus, are highly coordinated courses. Each course uses a department-approved common course syllabus, grading standards, and pacing chart. Moreover, all college algebra and precalculus sections use common assessments/exams, a common course final, and prescribed grading rubrics created by the faculty course coordinators. For each course, all exams/assessments given in fall 2020 virtual courses were the same as those given in fall 2019 face-to-face courses. In fall 2019, the department offered 30 sections of college algebra and 20 sections of precalculus, enrolling 987 students and 640 students, respectively. In fall 2020, the department offered 29 sections of college algebra and 15 sections of precalculus, enrolling 1101 students and 577 students, respectively. Since there were no curricular changes in either course from fall 2019 to fall 2020 other than moving from a face-to-face to virtual format, examining freshmen student outcomes in these two courses provides a controlled comparison between the two modalities of delivery. There were no statistically significant differences at the .01 level between fall 2019 and fall 2020 for either course for either average course grade or course success rate (Table 7). Thus, taking college algebra or precalculus in a face-to-face or virtual platform

had no measurable effect on overall student performance in either course.

Table 7

Comparison of Student Outcomes in College Algebra and Precalculus, F2019 and F2020

	Fall 2019			Fall 2020			t-test statistics		
	<i>N</i>	\bar{x}	S_x	<i>N</i>	\bar{x}	S_x	<i>df</i>	<i>t</i>	<i>P</i>
College Algebra									
<i>Course Grade</i>	822	2.448	1.100	910	2.574	1.170	1730	-2.293	.022
<i>Success Rate</i>	822	.766	.423	910	.769	.421	1730	-0.148	.882
Precalculus									
<i>Course Grade</i>	530	2.029	1.140	471	2.100	1.239	999	-0.944	.345
<i>Success Rate</i>	530	.656	.475	471	.665	.472	999	-0.300	.764

Summary

We restate the first research question below:

RQ1. How did academic outcomes for freshman students taking virtual courses compare with freshman students from previous semesters taking face-to-face courses?

Institutional data trends showed that student outcomes for freshmen enrolled in GE mathematics courses in fall 2020 were comparable with those from previous fall semesters. While gender and URM status equity gaps were observed during the fall 2020 virtual semester, these gaps were (non-significantly) smaller for URM males, URM females, and non-URM males compared with those from the previous fall 2019 face-to-face semester. Non-URM female students had significantly higher student outcomes in the fall 2020 virtual semester than in the fall 2019 face-to-face semester.

Moreover, a comparison of student outcomes with those from the five previous fall semesters showed a (non-significantly) increase in student outcome trends. As mentioned previously, real-time assessments/exams were given in a virtual format in fall 2020. Factors such as having access to working technology, including sufficient internet bandwidth, having a quiet and/or private place to take exams, as well as issues related to academic integrity may have contributed to student performance. However, a comparison of two highly standardized multi-section courses showed that fall 2020 course outcomes were comparable to those in fall 2019. In summary, there was evidence that the academic achievement of freshman students enrolled in mathematics virtual courses in fall 2020 was comparable to that of previous freshman students enrolled in face-to-face courses in previous fall semesters.

Course Preferences

The mathematics student survey was separated into eight blocks of questions, including Likert-scale items, background information, and the two open-ended questions mentioned earlier. The eight blocks included:

1. Students' experiences taking virtual courses.
2. Amount of time spent preparing for and taking virtual courses.
3. Responsibility and stress levels.
4. Overall mathematics course experience.

5. Technology and space.
6. Transportation and parking.
7. Demographic information.
8. Open-ended questions: What was the greatest benefit and greatest challenge for you taking mathematics classes in a virtual format?

Survey questions for blocks 1 and 2 were asked using a five-point Likert scale. A lower value (1 or 2) on the Likert scale indicated a strong or somewhat preference for VT classes, a higher value (4 or 5) indicated a strong or somewhat preference for FF classes, and a value of 3 indicated no preference either way. Codes for blocks 3-6 were also based on a five-point Likert scale with response choices dependent upon the questions being asked; block 7 asked about student background information (Appendix 1).

Results

On the survey, freshman students were asked, “Given the choice, would you prefer to have taken this mathematics course in a virtual teaching format or face-to-face teaching format? Table 8 gives the cell frequencies and marginal proportions by gender and URM status.

Table 8*Freshmen student preference for virtual or face-to-face mathematics courses*

	Prefer Virtual Format		No Preference		Prefer Face-to-Face Format	
	Male	Female	Male	Female	Male	Female
URM	45	84	41	78	198	363
Non-URM	36	78	40	62	154	167
Total by gender	81 (15.8%)	162 (19.5%)	81 (15.8%)	140 (16.8%)	352 (68.4%)	530 (63.7%)
Total overall	243 (18.1%)		222 (16.5%)		882 (65.5%)	

Of the 1346 students in the sample, 18.1% indicated a preference for virtual format classes, with female students' preference rate of 19.5% slightly higher than that for male students (15.8%). Likewise, 65.5% indicated a preference for face-to-face format classes, with male students' preference rate of 68.4% slightly higher than that for female students (63.7%). About one-sixth (16.5%) of both male and female students indicated no preference. Comparing these three preference groups by URM group status ($n = 809$) and non-URM group status ($n = 537$) showed that 15.4% of URM students and 21.2% of non-URM students preferred VT format; 69.3% of URM students and 59.8% of non-URM students preferred VT format; and 15.3% of URM students and 19.0% of non-URM students indicated no preference.

Freshman students' experiences in the virtual mathematics courses seemed to vary. Fifty-three percent of the students in the sample reported that they could communicate effectively with the instructor and peers via online tools. Yet, more than half of the students reported that they kept their video screens on for none or

little of the time during synchronous class sessions. While access to working computers and the internet was generally not a challenge for most students, more than one-fourth of the respondents indicated that having a quiet place to prepare for classes was very (14.3%) or extremely (12.4%) challenging. Not having to commute, find a parking place, or pay for parking was a benefit for more than sixty percent of respondents. While a third of the students (33.3%) thought that the VT experience was better than they had expected, one-fourth (25.2%) thought it was worse. Unsurprisingly, nearly seventy percent of students in the sample indicated that their overall stress levels were somewhat (24.4%) or much greater (44.1%) in fall 2020 than in fall 2019.

Comparison of URM student responses with those of non-URM students showed that URM students preferred FF courses over VT courses at a significantly higher rate than did non-URM students ($t = .3504, p < .001$), despite neither group reporting more experience in virtual courses prior to the fall 2020 semester ($t = -.895, p > .3$). URM students reported having significantly higher levels of challenge having access to a working computer and consistent internet than did non-URM students ($t > 3.9, p < .001$). Access to a quiet place to take synchronous classes and to study appeared to be even more of a challenge for URM students than for non-URM students ($t > 7.3, p < .001$) (Table 9).

Table 9*Comparison of URM and non-URM students on selected survey items*

Variable	URM students		Non-URM students		t-test statistics		
	\bar{x}	S_x	\bar{x}	S_x	df	t	p
Prefer VT v. FF	3.92	1.227	3.68	1.251	1344	3.504	<.001**
Computer access	1.65	.936	1.46	.810	1254	3.976	<.001**
Internet access	2.20	1.091	1.95	.990	1222	4.428	<.001**
Quiet place for classes	2.67	1.324	2.16	1.210	1214	7.316	<.001**
Quiet place to study	2.81	1.379	2.22	1.265	1214	8.114	<.001**
Prior exper. in VT	2.02	.848	2.06	.819	1342	-.895	.371

More than one-fourth (28.3%) of URM freshman students reported that having access to a quiet space to take classes was “very challenging” or “extremely challenging” as compared with 14.0% of non-URM students. Moreover, more than a third (33.8%) of URM students reported that having access to a quiet space to study was very or extremely challenging as compared with 16.2% for non-URM students. These rates were highest for URM female students, with 30.8% and 36.6% reporting these higher levels of challenges for class space and study space, respectively.

Regression analysis was used to determine the prediction of students’ preference for virtual or face-to-face teaching. Using a combined hierarchical/stepwise algorithm, we identified three key sets of independent variables: demographic and high school achievement variables, items about their general experiences during the pandemic, and items specifically about their virtual courses.

These sets were forced into the equation in sequence. Our logic was that students' demographic and high school variables occur first; their general experiences formed the context for their course experiences over the past year. We then asked a series of questions about those virtual course experiences. Within each set, variables were entered stepwise. These were the variables in each set:

1. Demographic and High School Achievement Variables: age, high school GPA, SAT verbal score, SAT math score, dichotomized gender, URM status, first-generation, and financial aid.
2. Pandemic Experience: Responsibility and stress levels (Block 3, four items), technology and space challenges (Block 5, four items), transportation and parking (Block 6, four items), prior VT experience, and working at a paid job.
3. VT Course Experience: Students' VT and FF experiences (Block 1, 7 items), time spent on classes (Block 2, 5 items), overall VT mathematics course experiences (Block 4, 4 items), and mathematics course grade.

When we ran the first regression, four variables from Set 1 entered the equation: URM/Non-URM status, financial aid, gender, and SAT math score. These variables, along with the variables from Set 2, were used for the second regression. The only variable from Set 1 to stay in the equation was URM status. Six variables from Set 2 entered the equation: not driving to campus, overall stress, quiet

space to study, not living on campus, working at a paid job, and school-related stress. These seven variables, along with the variables from Set 3, were used for the third regression. Eight variables in total entered the third regression: URM status (Set 1); not driving to campus, overall stress, and not living on campus (Set 2); and understanding in VT/FF, overall experience in VT/FF, performance in VT/FF, and overall math experience in VT (Set 3). We then recomputed the regression using only this set of eight variables. These variables are shown in Table 10.

Table 10

Regression analysis of student preference for taking VT v. FF courses

Variable	Standardized beta	<i>t</i>	<i>p</i>
Understanding of the material comparing fall 19 with fall 20	.217	6.240	< .001**
Overall course experience comparing fall 19 with fall 20	.208	5.907	< .001**
Overall course performance comparing fall 19 with fall 20	.137	3.845	< .001**
Overall VT math experience	-.124	-3.487	.001*
SAT-Verbal	-.083	-2.944	.003*
Underrepresented minority status	-.060	-2.366	.018
Prior VT experience	.058	2.593	.010
First in family to attend college	-.054	-2.171	.030
Overall stress level	.054	2.015	.044
Number of units	-.046	-1.997	.046
df = 1067 R = 0.728 R ² = 0.530 F = 27.502 sig. F < 0.001			

Use of a hierarchical algorithm allowed us to partition the explained variation as follows:

Variable Set	Total R ²	Change in R ²
Set One: Demographic Variables	.027	.027
Set Two: Pandemic Experience Variables	.218	.191
Set Three: VT Course Experience Variables	.494	.276

Thus, these three sets of variables explain nearly half of the variation (49.4%) in student preference for VT or FF teaching. This analysis shows that students' opinions about the value of VT were primarily driven not by demographic characteristics nor by events and pressures outside the courses. Rather, they were predicted by characteristics of the courses themselves based on the student's perceptions of their understanding of the material in the virtual setting.

Course Preference and Course Outcomes

Mathematics course outcomes for freshman students who indicated that they strongly or somewhat preferred VT courses were compared with those of students who strongly or somewhat preferred FF courses (students who indicated that they had no preference were not included in this analysis). Of the 1346 respondents, 243 (18.1%) indicated a preference for VT courses while 882 (65.5%) indicated a preference for FF courses, a total of 1125 (83.6%) of the sample. T-test comparisons between these two preference groups showed that the VT group had a significantly higher average course grade ($t = 7.057, p < .001$) and success rate ($t =$

5.840, $p < .001$) than did the FF group, with differences of .54 (95% CI = [.40, .68]) grade points and 13.7 [9.0, 18.4] percentage points. Controlling for gender showed that the VT preference group of male students had a significantly higher average course grade ($t = 2.879$, $p < .005$) than the FF preference group of male students by .44 [.17, .71] grade points. Likewise, among female students, there was a difference between VT and FF preference groups for both average course grade of .57 [.40, .74] grade points and success rate of 16.0 [.11, .21] percentage points both favoring the VT group. Each of these differences was statistically significant at the .001 level (Table 11). Academic predictors, including HSGPA, SAT-V, and SAT-M were compared for male and female students. No significant differences in these variables were found for male students preferring VT over FF courses ($t < 1$, $p > 0.1$). Statistically significant differences were found favoring female students preferring VT over FF courses for SAT-V ($t = 2.11$, $p < .05$) and SAT-M ($t = 2.53$, $p < .05$).

Table 11

Comparison of fall 2020 course outcomes for students preferring VT v. FF mathematics courses

	Prefer VT courses			Prefer FF courses			t-test statistics		
	<i>N</i>	\bar{x}	S_x	<i>n</i>	\bar{x}	S_x	<i>df</i>	<i>t</i>	<i>p</i>
All students									
Average grade	243	2.94	1.022	882	2.40	1.220	450	7.057	< .001**
Success rate	243	.905	.293	882	.768	.423	549	5.840	< .001**
Males									
Average grade	81	2.70	1.237	352	2.26	1.248	431	2.879	.004*
Success rate	81	.815	.391	352	.733	.443	132	1.656	.100

Greatest Benefit and Challenge of Virtual Courses

At the end of the survey, students had the opportunity to respond to two open-ended questions per the CBMS (2020) survey:

Q1. What was the greatest benefit for you taking mathematics classes in a virtual format?

Q2. What was the greatest challenge for you taking mathematics classes in a virtual format?

There were 1234 responses for Q1, representing 91.6% of the freshman students in the sample. An open coding qualitative scheme based on keyword frequencies was used to categorize the responses. Six categories emerged for the greatest benefit of VT: Commuting advantages, increased course access, scheduling advantages, learning new skills, no greatest benefit (explicitly stated), and others. In cases where a respondent mentioned more than one benefit, the benefit given first was used for coding (Table 12). Commuting advantages and increased course access were most often identified as the greatest benefits by student respondents, accounting for 66.7% of the responses. Responses in course access centered around the usefulness of having recorded lectures and access to online course materials. Seven percent of the respondents explicitly stated that they found no greatest benefit in taking virtual mathematics courses (Figure 3).

Table 12*Greatest benefit and greatest challenge of virtual classes identified by freshman students*

Greatest Benefit of Virtual Classes	All Students	Students Preferring VT	Students Preferring FF
Commuting advantages	35.7%	34.2%	34.8%
Increased course access	31.0	34.6	29.9
Flexibility of schedule	11.3	14.1	10.2
Learning new skills	7.5	9.8	7.1
No benefits	7.5	1.7	10.3
Other	7.1	5.6	7.7
Greatest Challenge of Virtual Classes			
Lack of student engagement	22.5 %	20.3%	24.2%
Perceived impact on course performance	17.9	9.9	21.2
Feelings of disconnectedness	17.9	15.5	16.9
Faculty-student communication	17.6	16.8	18.1
Space/technology concerns	12.2	18.1	10.2
Increased time demands	4.1	5.2	3.8
Other	7.8	14.2	5.7

There were 1256 responses for Q2, representing 93.3% of the freshman students in the sample. As before, an open coding qualitative scheme based on keyword frequencies was used to categorize the responses. Seven categories emerged for the greatest challenge of VT: lack of student engagement, perceived impact on course performance, faculty-student communication, feelings of disconnectedness, space/technology concerns, increased time demands, and other (only three students stated that there was no greatest challenge). Lack of student engagement was most often identified as the greatest challenge by student respondents, accounting for 22.5% of the responses. Perceived impact on course performance, faculty-student communication, and feelings of

disconnectedness each accounted for about 18% of responses (Figure 4).

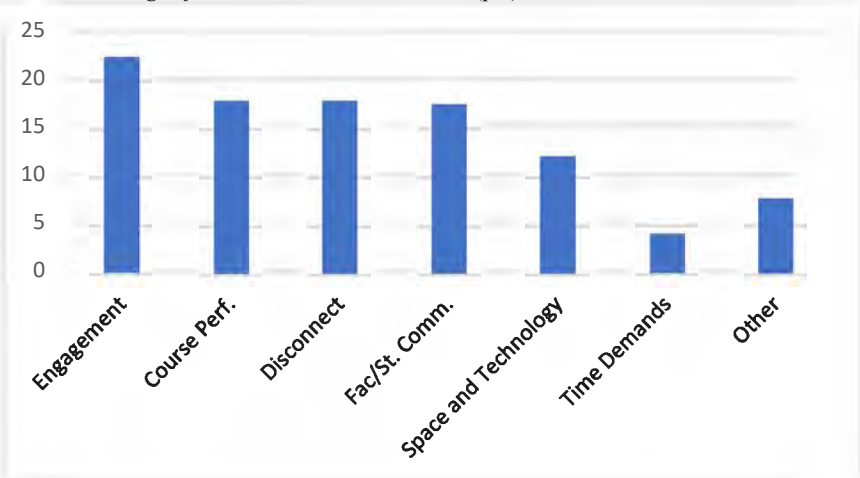
Figure 3

Greatest benefit of virtual mathematics courses (pct)



Figure 4

Greatest challenge of virtual mathematics courses (pct)



We compared student response frequencies for the 243 students preferring virtual classes (VT) with those of the 882 students

preferring face-to-face classes (FF). The response rates for Q1 and Q2 were 96.2% and 95.4% for the VT group and 91.1% and 93.4% for the FF group, respectively. The VT and FF groups were comparable for greatest benefit identified in all but one category: more than one-tenth of the FF group explicitly stated that there was no greatest benefit compared with less than 2% of the VT group. The VT and FF groups were comparable for the greatest challenge identified in four categories: engagement, communication, disconnectedness, and time demands. However, 21.2% of students preferring FF classes identified perceived impact on course performance as the greatest challenge of virtual classes as compared with 9.9% of students preferring VT classes. Interestingly, 18.1% of the VT group identified space/technology concerns as the greatest challenge, compared with 10.2% of the FF group.

Summary

We restate the second research question below.

RQ2. What factors influenced freshman students' preferences for taking virtual or face-to-face courses?

Measurable differences were found for both experiences and outcomes in virtual mathematics courses based on course modality preference. Students who preferred face-to-face classes identified understanding of the material as the primary factor, along with course experience and performance. Having consistent internet access and a quiet place to study were identified in survey

responses as being challenges, especially for URM students, but did not appear as significant predictors in the regression equation. Similarly, benefits associated with commuting and time flexibility were identified in survey responses as benefits but did not appear in the regression equation. Prior experience with online courses was not a factor in student preference of VT or FF classes, nor were socioeconomic or prior academic variables other than URM status and SAT-V score, which, though statistically significant, were relatively weak predictors of course modality preference. URM students reported greater challenges associated with internet access and study space than did non-URM students. Nonetheless, the set of students indicating a preference for VT mathematics courses reflected the four gender/URM status group proportions in the larger sample, with non-URM female students being (non-significantly) overrepresented in the VT group (32.1%) compared to the overall sample (22.8%). Open-ended responses showed that two-thirds of students identified the greatest benefit of virtual classes as commuting advantages or increased course access. Conversely, more than one-fifth of the students identified a lack of student engagement as their greatest challenge. Students preferring face-to-face courses identified perceived impact on their course performance at more than twice the rate of students preferring virtual courses

Discussion

The results presented here suggest a complex picture of freshman students' collective experience in taking virtual mathematics courses during the pandemic. While student course outcomes in mathematics courses were at the same level as those in pre-pandemic semesters, there was evidence that many students *felt* that the virtual platform negatively impacted their academic performance (e.g., Saw et al., 2020). Consistent with the report by Cao et al. (2020), seven out of ten students reported higher levels of anxiety in fall 2020 over fall 2019. Factors associated with perceived impact on content understanding and course performance measurably affected student preference for face-to-face versus virtual teaching platforms and may have attributed to increased anxiety levels as well. Female students who preferred virtual teaching courses over face-to-face courses had higher academic predictors and higher course outcomes. However, male students who preferred virtual teaching courses over face-to-face courses did not have higher academic predictors yet had higher course outcomes. Moreover, for both male and female students, actual course outcomes were not a predictor of preference for virtual or in-person courses. Although equity gaps neither widened nor narrowed between gender and underrepresented minority status subgroups, URM students reported challenges associated with study space at twice the rate of non-URM students. This finding is

consistent with McCormick's observation that the impacts of distance learning are not equal among students (2020).

Student comments on the two open-ended questions further support these observations. Among students preferring virtual teaching courses, 35% indicated that having online access to course notes and the recorded lecture was a major benefit as compared to 28% of students who preferred face-to-face courses. Similarly, only 9% of students preferring virtual teaching courses indicated that the virtual modality had an impact on their course performance, compared with 22% of students preferring face-to-face courses. Specific comments from both groups indicated that many students were determined to be successful despite the challenges associated with taking courses in a virtual format.

Regression analyses showed that demographic variables, including gender and URM status, accounted for less than three percent of the variation in student course modality preference. Variables associated with the general pandemic experience, such as responsibility and stress levels as well as technology access, accounted for 19% of the variation. Variables directly associated with virtual course experience accounted for 28% of the variation in student preference for face-to-face versus virtually taught courses. This observation supports Anderson's (2011) model for e-learning, namely, that the actual course experience is far more impactful on shaping student attitudes towards online learning than are factors

associated with student background. Since each of the mathematics courses in the current study was taught in a synchronous modality, it is possible that the real-time setting for student-to-student and student-to-instructor interactions played a role in shaping student attitudes as well.

As stated earlier, the current study is in large part a real-time program analysis that delved deeply into documenting both student outcomes and student experiences in virtually taught mathematics courses for freshman students. This study did not aim to attribute causality for student preference or achievement in virtually taught courses. Rather, its purpose was to try to identify factors that were salient for the students' experiences, and achievement in a virtually taught mathematics course. What emerged was a complex structure that indicates, unsurprisingly, that a variety of factors may play into students' perceptions of their experience. There was evidence that factors associated with the students' perceived learning of the material was central in shaping student preference for in-person as compared with online learning. This suggests that the student, rather than programmatic structures, may be the best resource to determine which type of learning modality is optimal for that individual.

Limitations and Further Research

As with any research, this study has limitations. First, all data were collected at a large public comprehensive institution in an

urban area. While this setting helped to create a diverse sample of students it is unclear the extent to which the results presented here are applicable to other types of institutions. Second, surveys were given towards the end of the semester so that students had enough time to experience virtual learning in their mathematics courses. Thus, student participants were limited to those who were still enrolled in and/or still attending virtual classes at that point in the semester. Institutional records showed that approximately 4.9% of freshman students enrolled in a mathematics course at the beginning of the fall 2020 semester either received a grade of no credit, withdrawal, or unauthorized withdrawal; thus, these students were not represented in the study. Third, all courses in this study were taught in a synchronous environment. Asynchronous, HyFlex, or other blended course modalities may result in different academic experiences and outcomes.

As stated earlier, this study was essentially a large-scale program evaluation with data gathered in real-time. The study found evidence that a non-trivial proportion of freshman students – between 15 and 20 percent – not only preferred virtual over face-to-face mathematics courses but achieved at an equal or higher level than students in face-to-face classes. While the two open-ended questions provided a snapshot of students' expressed experiences, further research is needed to identify specific factors that may be useful in guiding and supporting students who are considering

taking virtual mathematics courses. These factors may also be relevant for students in other STEM disciplines.

Based on this study's results, offering virtual and face-to-face options for multi-section first-year mathematics courses may be a viable way to meet a wider range of student needs and preferences and effectively utilize resources as institutions move into a post-pandemic era (Shalby, 2021). It will be critical for university leaders, faculty, and students to be included in meaningful discussions about how this can best be achieved to ensure equity and access for all students.

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Appendix 1: Freshmen Mathematics Students Survey Codes and Data Summary

Block 1: Students' Experiences. The following items ask you to compare your perceptions and experiences in your VT and FF mathematics courses (response frequencies given in percent).

	VT much better (1)	VT somewhat better (2)	Both about the same (3)	FF somewhat better (4)	FF much better (5)	Mean	SD
Understanding of material	4.2	11.3	27.5	25.3	31.6	3.69	1.133
Attendance in class	17.7	8.5	54.8	7.0	11.9	2.87	1.150
Participation in class	5.5	11.2	33.7	25.6	23.8	3.51	1.133
Academic integrity of class	5.6	6.6	63.1	13.5	11.1	3.18	.915
Receiving feedback on work	8.0	12.2	35.1	24.0	20.4	3.37	1.170
Overall performance in the course	6.2	13.8	28.8	23.3	27.8	3.53	1.206
Overall experience in the course	6.7	11.4	28.6	23.8	29.3	3.58	1.210

Block 2: Time Spent on Classes. The following items ask you to compare the amount of time you spent on the following activities this semester Fall 2020 in a VT setting as compared to the Fall 2019 semester in a FF classroom setting (response frequencies given in percent).

	VT much more time (1)	VT more time (2)	Both about the same (3)	FF more time (4)	FF much more time (5)	Mean	SD
Time spent doing homework	14.9	20.6	37.3	17.2	10.0	2.87	1.164
Time spent studying for exams	11.5	18.6	39.0	21.2	10.6	3.01	1.134
Time spent on projects/writing assn.	9.1	18.3	45.5	17.8	9.2	3.00	1.047
Time spent interacting with other st.	2.1	3.2	10.9	20.0	63.7	4.40	.949
Time spent interacting with instruct.	3.2	6.3	20.7	28.4	41.5	3.99	1.073

Block 3: Responsibility and Stress Levels. The following items ask you to compare your responsibility and stress levels in Fall 2019 and Fall 2020 (response frequencies given in percent).

	Much greater in 2019 (1)	Somewhat greater in 2019 (2)	About the same (3)	Somewhat greater in 2020 (4)	Much greater in 2020 (5)	Absent	SD
Family-related responsibility level	44	66	32.9	25.1	21.0	3.56	1.031
Work-related responsibility level	59	82	36.4	26.1	23.3	3.52	1.113
School-related responsibility level	60	11.8	24.3	25.4	29.6	3.65	1.130
Overall stress level	56	59	19.8	24.4	44.1	3.96	1.174

Block 4: Overall Mathematics Course Experience. The following items ask about your overall experience of taking mathematics courses in a VT format this semester (response frequencies given in percent).

	Strongly prefer VT (1)	Somewhat prefer VT (2)	About the same (3)	Somewhat prefer 2F (4)	Strongly prefer 2F (5)	Absent	SD
Learn concepts/units better in and pass the class successfully etc.	44	12.6	28.8	47.3	12.1	3.44	1.084
Engage more in class or do more challenging tasks	59.1	22.6	26.4	18.2	12.1	3.41	1.081
Learn more fully and accurately about various mathematics	52.2	14.1	25.4	26.3	19.4	3.48	1.085
Overall experience taking mathematics courses in VT format	Strongly prefer VT (1) 43	Strongly prefer 2F (5) 18.4	About the same (3) 42.2	Somewhat prefer 2F (4) 22.6	Strongly prefer 2F (5) 12.1	3.41	1.071
Enjoy VT or 2F format for taking mathematics	Strongly prefer VT (1) 12	Somewhat prefer VT (2) 11.8	Not preferred (3) 14.4	Somewhat prefer 2F (4) 26.7	Strongly prefer 2F (5) 44.1	3.49	1.225
Compare to other math courses taking a VT math course this	Much prefer (1) 41	None (2) 11.8	About the same (3) 26.7	None (4) 21.4	Much better (5) 12.1	3.41	1.011
Overall experience taking mathematics courses in VT format	Strongly prefer VT (1) 11	Strongly prefer 2F (5) 14.7	About the same (3) 22.8	Somewhat prefer 2F (4) 23.9	Strongly prefer 2F (5) 22.1	3.41	1.061
Prefer VT or 2F format for non-class courses	Strongly prefer VT (1) 42	Somewhat prefer VT (2) 11.8	Not preferred (3) 18.2	Somewhat prefer 2F (4) 25.9	Strongly prefer 2F (5) 24.3	3.48	1.089

Block 5: Technology and Space. How challenging were the following aspects of technology and space taking classes in a VT setting for you (response frequencies given in percent)?

	Not at all ch. (1)	Slightly ch. (2)	Mod. ch. (3)	Very ch. (4)	Extremely ch. (5)	Mean	SD
Consistent computer access	66.1	19.5	12.6	2.6	1.2	1.57	.302
Consistent internet access	52.9	36.5	15.4	7.5	3.4	2.10	1.059
Cons access to quiet place for class	51.0	23.5	20.9	13.2	9.4	2.47	1.504
Cons access to quiet place to prepare	29.3	22.9	21.0	14.3	12.4	2.58	1.365

Block 6: Transportation and Parking. The following items ask about transportation and parking while taking classes in a VT format this semester (response frequencies given in percent).

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree/disagree (3)	Somewhat agree (4)	Strongly agree (5)	Mean	SD
VT was worth it since I did not have to drive to campus	10.0	10.6	16.3	28.8	34.4	3.27	1.214
VT was worth it since I did not have to find a parking place	9.0	7.1	19.5	28.8	35.7	3.73	1.276
VT was worth it since I did not have to pay for parking	7.8	6.9	16.6	23.5	45.5	3.90	1.154
VT was worth it since I did not have to live on or near campus	11.6	11.4	26.3	17.9	29.9	3.37	1.360

Block 7: Background Information. The following items ask about background information (response frequencies given in percent).

	Act 1 (1)	Act 2 (2)	Co (3)	Sub (4)	Eng DS (5)	Mean	SD
3-yr area of study	12.1	18.0	31.4	33.7	12.7		
First experiential taking course in VT setting	19.6	11.0	21.0	23.8	24.7	2.28	.887
3-yr of course taken in Fall 2020	1-6 (1)	7-11 (2)	12-17 (3)	18-23 (4)	24-30 (5)	2.89	.764
3-yr of math/math/science/math	0 (1)	1-6 (2)	7-11 (3)	12-17 (4)	18-23 (5)	1.88	1.287