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Abstract

To students and families already struggling to afford college tuition and fees, spending an additional $1,240 per year on books and supplies can be a breaking point. This cost constitutes as much as 39% of tuition and fees at a community college and 14% of tuition and fees at a four-year public institution (data obtained from the 2019-20 College Board survey for full-time undergraduate students). Moreover, due to the coronavirus pandemic, the demand for digital textbooks is surging and the problem is compounded by the fact that without on-campus resources, including library reserve textbook collections, students are facing more barriers to access course content. Existing research also points to a negative impact on student grades, retention rates, and graduation time when there is lack of access to primary course materials.

Open textbooks and open educational resources (OER) present a viable alternative to costly publisher content. Defined, open educational resources are teaching and learning materials freely available for everyone to use and are typically openly licensed to allow for re-use and modification by instructors. At New York City College of Technology – CUNY, the college's library began an OER initiative in fall 2014 to introduce faculty to OER as an alternative to traditional textbooks, and since then faculty have adopted OER across 26 of 28 academic departments and 116 courses – alleviating great financial strain and increasing access to course materials.

The main objective of this paper is to investigate the association between the use of OER in engineering programs and student academic performance and retention rates. Analysis of early data demonstrates that for course sections where OER was used, retention rates increased significantly, and withdrawal rates lowered significantly.

1. Introduction

The last decade has seen an increase in the open education movement including open courseware, open textbooks, and Massive Open Online Courses (MOOC). The main focus of this movement is on broadening access to information through the use of open and free content. Bliss and Smith [1] explain the usefulness of this movement: "The implicit goal was to equalize access to disadvantaged and advantaged peoples of the world – in MIT's language, to create 'a shared intellectual Commons'." This open movement and its ethos have been something of an antidote to the disproportionate inflation of textbook costs over the past two decades [2], with the average expense for books and supplies estimated at $1,240 per year for full-time students [3].

Open educational resources (OER) are openly-licensed, freely available, educational materials that can be modified and redistributed. They can include any type of educational resource, from syllabi to full courses. Hewlett Foundation defines OER as: "Open Educational Resources are teaching, learning and research materials in any medium – digital or otherwise – that reside in

the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions [4]."

The two main benefits that OER can bring to students are cost savings [5] and access to quality education [6]. This is especially relevant to the student population at City Tech, 60% of whom are considered economically disadvantaged, and belong to the most racially, ethnically, and culturally diverse institution of higher education in the northeast United States: 30% of our students are African American, 32% are Latino, 21% are Asian or Pacific Islanders, and 12% are Caucasian [7].

The main benefit of OER among instructors is the freedom to adapt OER to their specific instructional needs. Currently, some of the challenges to using OER are uneven subject availability (much content is available for General Education courses), the time involved in locating and adopting material, and the lack of support (i.e., institutional resources) for creating new OER material.

The goal of this study is to explore whether teaching with OER in place of proprietary and other paywalled materials has any impact on student retention and academic performance.

2. Open Education Resources at City Tech

While there are structural impediments to adopting OER, there are emerging programs, typically at local and state levels [8], to increase faculty awareness and use of OER. At City Tech, the college's efforts began in fall 2014 with a signature faculty professional development program called the "OER Fellowship," in which faculty volunteer to replace a traditional textbook with curated course material that is cost-free and publicly accessible via the college's open-source digital platform, the City Tech OpenLab [9]. Upon completion of the OER Fellowship, faculty receive a stipend for participating in seminars, identifying materials and curating the OER, and then teaching with the course material over the next academic term. The OER course redesign process ensures that students have access to course material before, during, and after their studies, as the program requires course content be made available via a public website that does not require authentication (on the OpenLab platform) as opposed to a proprietary course management system that limits access to course materials to the duration of the semester.

The college's program has expanded since the university was awarded $4 million annually (AY 2017-18 to present) from New York State to scale-up OER efforts [10]. Beginning with the first inaugural cohort of 3 faculty in spring 2015, the program has steadily increased to 18 faculty in 2016, and up to at least 30 faculty per year from 2017 to the present.

3. Methodology

3.1 Participants and settings

In this paper we focus on OER adoption in the college's engineering departments: OER has been implemented in 24 courses across 9 departments (illustrated in Table 1). Additionally, the course curriculum remained consistent during OER adoption. Curriculum revisions are initiated at the

department level, with minor and major curriculum modifications taken up based on protocols prescribed by the college and university. No courses included in this study went through any minor or major curriculum modifications during this time. To control for unexpected variables including courses that were not offered or faculty who were not assigned to courses, we limited the data analysis to 14 of the 24 courses to ensure data validity. As the analysis outlines below, 8 of the courses ran with partial adoption of OER (not all sections offered used OER), and 6 courses had full OER adoption (all sectioned used OER).

Table 1: OER initiative in engineering departments at City Tech

No.	Course Code	Course Name	Engineering Department	First Term Eligible for OER
1	CMCE 2321	Construction Management II	Construction Management Technology	2016 Fall
2	ENT 1102	Health and Safety in Production	Entertainment Technology	2016 Fall
3	TCET 2102	Analog and Digital Telephony	Electrical Engineering & Telecommunications Technologies	2017 Fall
4	ARCH 1101	Introduction to Architecture	Architectural Technology	2018 Fall
5	COMD 2427	Typographic Design	Communication Design	2018 Fall
6	CST 1101	Computer Programming and Problem Solving	Computer Systems Technology	2018 Fall
7	CST 4714	Database Administration	Computer Systems Technology	2018 Fall
8	EET 1102	Techniques of Electrical Technology	Electrical Engineering & Telecommunications Technologies	2018 Fall
9	MECH 3550	Simulation and Visualization	Mechanical Engineering Technology	2018 Fall
10	TCET 3222	Satellite Transmission	Electrical Engineering & Telecommunications Technologies	2018 Fall
11	ENT 1201	Electricity for Live Entertainment	Entertainment Technology	2019 Spring
12	CET 4925	Internet of Things	Computer Engineering Technology	2019 Fall
13	COMD 3504	Communication Design Theory	Communication Design	2019 Fall
14	EMT 1130	Electromechanical Manufacturing Lab	Computer Engineering Technology	2019 Fall
15	EMT 2390L	Operating Systems Lab	Computer Engineering Technology	2019 Fall
16	ENT 3390	Sound for Multimedia	Entertainment Technology	2019 Fall
17	MTEC 1005	Physical Computing Skills Lab	Entertainment Technology	2019 Fall
18	TCET 4182	Telecommunications Capstone Project I	Electrical Engineering & Telecommunications Technologies	2019 Fall
19	COMD 3601	Information Design	Communication Design	2020 Spring
20	CST 4724	Data on the Web	Computer Systems Technology	2020 Spring
21	CMCE 2456	Soil Mechanics and Lab	Construction Management Technology	2020 Fall
22	ENT 1270	Sound I	Entertainment Technology	2020 Fall
23	ENVC 2401	Renewable and Hybrid Energy Systems	Environmental Control Technology	2020 Fall
24	MECH 2333	Advanced Strength of Materials II	Mechanical Engineering Technology	2020 Fall

In order to explore the potential effects of OER on student success, we focused on examining student course outcome measures (i.e., withdrawal rate, fail rate) and retention rates (i.e. semester-to-semester retention rate and one-year retention rate). We explored three different criteria for students enrolled in OER courses: (1) course withdrawal rate, (2) D-grade rate, and (3) course failure rate. Grade performance distribution (A-C grades) was not included in the outcome measures in order to mitigate uncontrolled variables including potential unconscious and conscious bias during grading [11, 12]. Selection of measurement criteria was also informed by the methodologies implemented in the largest multi-institution assessment study performed to date about the impact of OER on student success, from the Achieving the Dream's OER Degree Initiative [13]. Rather than examining course level performance metrics, the Achieving the Dream study instead measured overall student credits earned and cumulative college grade point

average. We identified the eight courses with sections taught by both OER and Non-OER instructors and compared the three rates in the OER and non-OER groups. With the six courses that offered all sections as OER, we compared grade distributions in the previous two semesters prior to using OER.

We examined two types of student retention rates in these fourteen courses: (1) one-semester retention rate and (2) one-year retention rate. A student is considered retained if they are enrolled or graduated within a semester or academic year. For example, if a student enrolled in Fall 2016, returned in Spring 2017, or graduated by Spring 2017, the student is considered retained semester-to-semester. Similarly, if a student was enrolled in Fall 2016 and returned in Fall 2017, or graduated by Fall 2017, the student is considered retained in one year.

3.2 Statistical tests

In this paper, we used Welch's t-test, which is less restrictive compared to the original Student's t-test. Welch's t-test does not assume that the variance is the same in the two groups, resulting in fractional degrees of freedom. Welch's t-test performs better than Student's t-test whenever sample sizes and variances are unequal between groups and yields the same result when sample sizes and variances are equal.

4. Results

4.1 Student academic performance

Table 2 shares the grade distribution between OER sections and non-OER sections taught in the same semester. The results indicate that overall course withdrawal rates of OER sections are statistically significantly lower than non-OER sections taught during the same semester, with $t(547) = 3.31$, $p < .001$, 95% CI: [2.6%, 10.2%]. In contrast, the overall D-grade ($t(441) = 0.48$, $p = .63$) and course failure rates ($t(444) = 0.92$, $p = .36$) between OER and non-OER sections are not statistically significantly different. With the majority of OER course sections, the D-grade and failure rates are relatively lower or in the same range as the non-OER sections. The D-grade rate difference ranges from -13.0% to +11.6%, and failure rate difference ranges from -6.8% to +12.9%.

Table 3 presents the trend of grade distribution for courses with all sections before and after adopting OER. After implementing OER, the withdrawal rates dropped in five out of six courses; course failure rate and D-grade rate show no clear trends.

In summary, courses that adopted OER have demonstrated a significant decrease in withdrawal rate, a relatively lower failure rate, and no obvious change in D-grade rate.

Table 2: Grade distribution comparison (OER versus non-OER sections taught in the same semester)

Course	OER Sections				Non-OER Sections			
	# of students	Withdrawal (%)	D-grade (%)	Fail (%)	# of students	Withdrawal (%)	D-grade (%)	Fail (%)
ARCH 1101 (2018 Fall)	34	20.6%	7.4%	11.1%	146	19.2%	4.2%	5.9%
COMD 3504 (2019 Fall)	18	0.0%**	5.6%	0.0%	36	22.2%**	0.0%	0.0%
CST 1101 (2018 Fall)	23	17.4%	10.5%	21.1%	570	13.9%	6.3%	8.1%
CST 4714 (2018 Fall)	24	0.0%	0.0%	0.0%	24	8.3%	4.5%	0.0%
CST 4714 (2019 Spring)	24	0.0%	0.0%	0.0%	24	0.0%	0.0%	0.0%
CST 4714 (2019 Fall)	24	4.2%	0.0%	0.0%	24	4.2%	13.0%	0.0%
EET 1102 (2018 Fall)	34	0.0%**	0.0%*	8.8%	72	11.1%**	6.3%*	15.6%
EMT 1130 (2019 Fall)	41	22.0%	0.0%*	25.0%	243	18.9%	2.0%*	28.9%
EMT 2390L (2019 Fall)	44	2.3%	11.6%*	2.3%	41	7.3%	0.0%*	0.0%
ENT 1102 (2016 Fall)	27	11.1%	4.2%	29.2%	26	19.2%	4.8%	23.8%
Total	**293**	**8.5%*** **	**4.1%**	**9.7%**	**1206**	**14.9%*** **	**4.8%**	**11.6%**

Note. D-grade (%) is the percentage of students who obtained a D grade out of the total students who completed the course (completed = total enrollment – withdrawal), Fail (%) is the percentage of students who failed the course out of the total students who completed the course; The asterisks (*) indicate significance levels: *** ($p < .001$), ** ($p < .01$), and * ($p < .05$);

Table 3: Grade distribution trends for courses before and after using OER

Course	OER Adopted Semester	OER Semester				One-semester Before OER Adopted				Two-semester Before OER Adopted			
		# of students	Withdrawal (%)	D-grade (%)	Fail (%)	# of students	Withdrawal (%)	D-grade (%)	Fail (%)	# of students	Withdrawal (%)	D-grade (%)	Fail (%)
CMCE 2321	2016 Fall	39	0.0%	2.6%	2.6%	21	4.8%	0.0%	0.0%		--		
COMD 2427	2018 Fall	36	0.0%*	8.3%	19.4%*	90	6.7%*	3.6%	2.4%*	108	2.8%	1.9%	2.9%*
ENT 1201	2019 Spring	33	0.0%	0.0%	9.1%	23	8.7%	4.8%	14.3%	20	0.0%	5.0%	5.0%
MECH 3550	2018 Fall	18	11.1%	0.0%	0.0%	19	15.8%	0.0%	0.0%	19	15.8%	18.8%	6.3%
MTEC 1005	2019 Fall	29	20.7%	4.3%	0.0%	32	9.4%	0.0%	0.0%	32	21.9%	16.0%	0.0%
TCET 3222	2018 Fall	16	0.0%	37.5%*	6.3%	15	0.0%	0.0%**	0.0%	14	0.0%	7.1%*	0.0%

Note. These six courses were taught all by OER instructors; The dashes ("--") indicate the course was not offered in the semester; The asterisks (*) indicate significance levels: *** ($p < .001$), ** ($p < .01$), and * ($p < .05$).

4.2 Retention rates comparison

Table 4 demonstrates that overall retention rates in OER sections are significantly higher when compared to non-OER sections taught in the same semester. For one-semester retention rates, the statistics are: $t(501) = -2.66$, $p = .008$, 95% CI: [1.6%, 10.7%], and the statistics of one-year retention rates are: $t(253) = -2.95$, $p = .003$, 95% CI: [3.5%, 17.6%].

Table 5 shows the student retention trends for the six courses with all sections using OER, comparing non-OER sections from the previous two semesters. Although none of the courses show statistical significance, five out of six had higher retention rates since adopting OER.

In summary, courses adopting OER have demonstrated a statistically significant increase in both one-semester and one-year retention rates.

Table 4: Retention rates comparison (OER versus non-OER sections)

Course	OER Sections			Non-OER Sections		
	# of students	one-semester retention (%)	one-year retention (%)	# of students	one-semester retention (%)	one-year retention (%)
ARCH 1101 (2018 Fall)	34	82.4%	67.6%	146	82.2%	65.8%
COMD 3504 (2019 Fall)	18	100.0%*	~	36	86.1%*	~
CST 1101 (2018 Fall)	23	82.6%	69.6%	570	82.1%	66.8%
CST 4714 (2018 Fall)	24	87.5%	87.5%	24	79.2%	79.2%
CST 4714 (2019 Spring)	24	87.5%	95.8%	24	91.7%	87.5%
CST 4714 (2019 Fall)	24	95.8%	~	24	91.7%	~
EET 1102 (2018 Fall)	34	88.2%	76.5%	72	81.9%	70.8%
EMT 1130 (2019 Fall)	41	65.9%	~	243	70.4%	~
EMT 2390L (2019 Fall)	44	95.5%	~	41	85.4%	~
ENT 1102 (2016 Fall)	27	88.9%	77.8%	26	76.9%	61.5%
Total	**293**	**86.3%****	**78.3%****	**1206**	**80.2%****	**67.7%****

Note. The tilde ("~") indicates full data is not yet available; The asterisks (*) indicate significance levels: *** ($p < .001$), ** ($p < .01$), and * ($p < .05$).

Table 5: Retention rate trends for courses with all sections using OER

Course	OER Adopted Semester	OER Semester			One-semester Before OER Adopted			Two-semester Before OER Adopted		
		# of students	One-semester retention (%)	One-year retention (%)	# of students	One-semester retention (%)	One-year retention (%)	# of students	One-semester retention (%)	One-year retention (%)
CMCE 2321	2016 Fall	39	84.6%	87.2%	21	81.0%	90.5%		--	
COMD 2427	2018 Fall	36	83.3%	77.8%	90	94.4%	88.9%	108	93.5%	90.7%
ENT 1201	2019 Spring	33	87.9%	75.8%	23	87.0%	65.2%	20	75.0%	70.0%
MECH 3550	2018 Fall	18	100.0%	88.9%	19	94.7%	84.2%	19	89.5%	73.7%
MTEC 1005	2019 Fall	29	79.3%	~	32	84.4%	84.4%	32	78.1%	59.4%
TCET 3222	2018 Fall	16	100.0%	100.0%	15	86.7%	93.3%	14	100.0%	92.9%

Note. The dashes ("--") indicate the course was not offered in the semester; the tilde ("~") indicates full data is not available yet.

5. Discussion

The first research question of this study asked if the academic performance (withdrawal rate, D-rate, and failure rate) in sections using OER differed from other sections of the same course in the same semester. The second research question asked if the academic performance (withdrawal rate, D-rate and failure rate) in sections that used OER differed from other sections of the same course in prior semesters. The results as shown in Table 2 and Table 3 indicate that courses implementing OER demonstrated a statistically significant decrease in course withdrawal rate, a relatively lower failure rate, and no obvious change in D-grade rate. Our results are in agreement with other studies [14] which demonstrate that lowering the cost of textbooks lowers withdrawal rates in community and senior colleges. The third research question of this study asked if OER improved student one semester and one-year retention rates. Our results in Table 4 and Table 5 demonstrate that the OER environment supports increased retention rates (both one semester and one year).

6. Conclusion and future work

Adopting OER can be an effective means of obviating the extreme cost of textbooks and is particularly important at New York City College of Technology (City Tech) because our student population is vulnerable to systemic inequities in the public education system that can impede academic progress. Our college setting is well placed to take up OER efforts with its established faculty driven programming lead out of the college's library, which has been sustained and expanded with funds awarded to the college as part of New York State's OER scale-up initiative, starting in 2017 and continuing into the 2020-21 academic year. The focus of this research was to examine whether there were any patterns in student performance and retention in courses specific to the college's engineering fields. Results from early data gathered indicate that courses using OER compared to non-OER courses had a decreased rate in student course withdrawal and a better retention rate. While the data did not yield a statistically significant change in grades (failing and D-grades), it is notable that student performance did not decrease. Future research will seek to include larger data sets to continue to compare these metrics against non-OER courses and examine further trends over time.

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