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Adopting Online Learning in College Developmental Education Coursework: Impact on Course Persistence, Completion, and Subsequent Success

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ABSTRACT

Online learning has been increasing rapidly at community colleges, especially in low-division high-demand coursework, such as developmental education. While existing studies have identified negative effects associated with online instruction in semester-long coursework in this particular setting, there is less evidence about how distance learning influences students' completion of developmental education coursework and, more importantly, their subsequent academic outcomes. This paper examines the impact of fully online instruction, compared with traditional face-to-face instruction, on both concurrent developmental course outcomes and downstream outcomes. We use an administrative dataset from a state community college system that includes longitudinal student-unit record data from more than 40,000 students enrolled in developmental education courses between 2005 and 2012, and employ a two-way fixed effects model that controls for selection both at the course- and student-level. We find that taking one's first developmental course through the online format reduces developmental course completion rate by 13 percentage points and subsequent enrollment in the gatekeeper course by 7 percentage points. Successful completion of developmental and subsequent gateway coursework represents critical milestones among community college students. This paper provides insight on how delivery format influences both the concurrent and downstream outcomes of developmental education students.

Introduction

Developmental education has been one of the most widespread and costly strategies used by colleges, especially open-access institutions, to provide academically weak students with additional training in key subject areas¹ (Chen & Simone, 2016). At community colleges, for example, 10% of all credits earned are from developmental coursework, which leads to a cost of almost \$4 billion annually (Scott-Clayton & Rodriguez, 2015). Due to the huge cost

CONTACT Di Xu Aix3@uci.edu School of Education, University of California, 3200 Education Dr, Irvine Although developmental coursework is provided in multiple fields of study, it is most prevalent in English and math; for the subject of English, it is a typical practice for colleges to assess and prepare students in reading and writing separately. The traditional developmental program typically consists of a sequence of multiple courses across several semesters, and students are assigned to different combinations of course requirements based on their initial assessment test scores in the corresponding subject area upon initial college enrollment (Boatman & Long, 2018; Chen, 2016; Grubb, 2013). For example, in a three-course math sequence, the lowest level of developmental math usually covers arithmetic, the middle level covers beginning algebra concepts, and the highest level prepares students for college algebra.

associated with developmental education and the large enrollment volume in these courses, many institutions have replaced or are considering replacing traditional face-to-face instruction with online instruction to save on costs and address demand.

Would students achieve similar learning outcomes when the developmental course content is delivered fully online rather than through traditional face-to-face delivery? Answers to this question likely have important policy implications for higher education success as well as for educational equality: first, timely completion of developmental courses plays a critical role in a student's college career; students required to take but failing to pass developmental education face academic hurdles in enrolling in other college-level courses and subsequent progression toward the degree (Jaggars & Bickerstaff, 2018). As a result, colleges tend to be particularly concerned with success rates in these courses. Additionally, studies consistently point out that participation in developmental education coursework was more common among traditionally underrepresented groups, including racial minority students, first-generation students, and students from low-income backgrounds (e.g., Bahr, 2010; Chen & Simone, 2016). Thus, supporting developmental education students to complete developmental education courses successfully and preparing them sufficiently to progress through subsequent gateway coursework becomes fundamental to reducing inequality between subgroups of students.

Whether a fully online format developmental course has different impacts on student outcomes compared with a face-to-face format remains unclear. On one hand, since the flexibility of online learning offers students freedom from constraints of time and space, advocates for online learning are optimistic about the potential of technology to better address individual needs through self-paced learning (Hart, Friedmann, & Hill, 2018; Jacob, Berger, Hart, & Loeb, 2016). On the other hand, online students are away from constant monitoring from instructors and have to learn course content independently and keep themselves on track. As a result, the success of online learning relies more on students' selfregulation during their learning process than do traditional learning contexts. Specifically, self-regulated learning requires students to constantly analyze the learning situation, set meaningful learning goals, use appropriate strategies to facilitate their mastery of course content, and reflect on and adjust their learning processes (Azevedo, Cromley, & Seibert, 2004). Since students enrolled in developmental courses are often academically underprepared and lack self-directed learning skills, a fully online learning environment may impose additional challenges (Xu & Jaggars, 2014; Xu & Xu, 2019).²

This paper extends the existing literature on distance learning in higher education by examining 2005-2009 through 2012 data for the impact of delivery format in developmental coursework – online versus face-to-face – on concurrent course outcomes in developmental coursework, as well as on students' subsequent persistence into and performance in gatekeeper courses. Gatekeeper courses are first college-level courses in English and math that are typically required for a college degree, and therefore represent critical milestones in a student's college career. We use a unique administrative dataset from an anonymous state community college system that includes longitudinal student-unit record data from four cohorts of students enrolled in developmental education courses. To address student nonrandom sorting by course delivery format, we exploit the fact that many students are

²A more detailed review of the existing literature on developmental education and online teaching and learning at community colleges can be found at https://drive.google.com/file/d/1Ly2lbyXPDZ3w58QWQ-HT6B0nFmnu6-8U/view

assigned to developmental courses in multiple subjects, which allows us to conduct withinindividual comparisons by using an individual fixed-effects model. We further include college-course fixed effects into our model, therefore comparing students enrolled in the same developmental education course at a specific college. Additionally, our dataset consists of a rich set of instructor characteristics. We control for instructor characteristics in some of our models to address the concern that online section instructors are different from face-toface section instructors within the same course.

It is important to note that since our data track students between 2005 and 2012, our findings do not capture possible advancement in technology in the last decade. Yet, the growing literature on the effectiveness of various technological tools converge to suggest that the mere presence of technological tools is not related to student outcomes unless it is thoroughly leveraged by the course instructor to engage learners and support learning (Jaggars & Xu, 2016; U.S. Department of Education, 2010). This would require strong commitment from the instructor, as well as sufficient level of institutional resources and support to enable instructors to incorporate the appropriate technological tools effectively into the instruction, both of which have been challenging at community colleges (Brinkley, 2016; Pagliari, Batts, & McFadden, 2009). As a result, the persistent performance gaps between online and in person instruction are observed in studies using more recent data. For example, using data from 2008 to 2016, Kozakowski (2019) identified a sizable negative impact of online learning compared with in-person support in remedial math courses. Our study further extends her work by including additional measures of downstream outcomes.

Data and research background

Data and research context

Data and state context

Our data include four cohorts of first-time college students, a total of 79,725 students, in an anonymous state community college system (referred to as ASCCS hereafter). These students were initially enrolled in ASCCS between fall 2005 and summer 2009, and were tracked until summer 2012, or at least four years since initial enrollment. Compared with the characteristics of typical two-year institutions nationwide based on data from the Integrated Postsecondary Education Data Systems (IPEDS), ASCCS institutions are more likely to be located in rural areas, smaller in enrollment size, more concentrated with white students, and are subject to lower graduation rates.³ The graduation rates are particularly low among students assigned to developmental education programs, where only 9.4% earn an associate degree in three years. In view of the low graduation rates, the state has implemented a series of initiatives aiming at improving postsecondary attainment and reducing the percentage of students assigned to college remediation. Yet, still about one third of the first-time college enrollees take developmental education courses during the period of the current study. In the meantime, similar to other community colleges, ASCCS has also expanded online learning in developmental coursework, partly to address the large demand for developmental education and partly to reduce the costs associated with it.

³Authors' calculation based on ASCCS administrative data for entering cohorts from 2005–06 to 2008–09.

Developmental sequence and course content

During the period of this study, ASCCS follows the traditional developmental sequence that consists of three courses for each subject area.⁴ In developmental math, the lowest level, such as "Basic Math Skills" or "Fundamental Math," teaches the fundamental operations of arithmetic and introductory elements of computations and statistics. The next level is elementary algebra, which incorporates the basic topics in arithmetic and algebra. The highest level is intermediate algebra, which prepares students for college algebra. In developmental writing and reading, the lowest level covers basic writing and reading skills, such as building vocabulary and constructing sentences. The middle level focuses on reading and writing a coherent essay. The highest-level writing covers the methods of paragraph development while the highest level reading develops word-attack skills, context clues, and skills of skimming and scanning college-level essays.

Students assigned to any level of the developmental sequence were required to complete all the developmental education requirements within two semesters of full-time enrollment. A Minimum grade of 2.00 (i.e., "C") was required in all developmental courses before advancing to the next course level.

Sample description

We limit our sample to students who have taken at least one developmental education course and focus on the first developmental course taken in each subject area. Approximately one third of the student body has attempted at least one developmental course (referred to as developmental students hereafter) and the analytical sample includes 41,781 developmental students with a total of 61,831 course enrollments, where approximately 10% (N = 3,557) of the students attempt at least one developmental course online. Of the 41,781 students in our analytical sample, 48% take developmental writing, 39% take developmental reading, and 83% take developmental math. About one fifth of the developmental students take both writing and reading. Since these students only have one downstream outcome in the subject of English, we randomly choose a course as the student's initial English developmental course. We also conduct a separate robustness check where we collapse the sample at the student-subject level and define the key explanatory variables as the proportion of credits taken through online in each subject area. The results are fairly consistent.

Table 1 provides summary statistics for students who take all of their first developmental courses face-to-face versus those who attempt at least one online. Compared with students who take a complete face-to-face course spectrum, the ever-online students⁵ are more likely to be older, female, black students, part-time students, and students with lower math placement test scores but higher reading and writing scores.

One unique feature of our dataset is that it includes a rich set of instructor characteristics that are often missing from the existing literature on distance learning. Table 2 presents the average demographic characteristics, degree attainment, and employment

⁴A detailed explanation of how students are placed into different levels of developmental education coursework can be found at https://drive.google.com/file/d/1Ly2lbyXPDZ3w58QWQ-HT6B0nFmnu6-8U/view.

⁵"Ever-online students" are defined as those who had ever taken an online course.

Table 1. Student characteristics by course delivery format.

	Took at least one online course	Took only face-to-face course
Age upon initial enrollment	24.6	22.8
	(8.22)	(7.26)
Female	65.7%	59.5%
Race		
White	45.7%	60.6%
Asian	0.5%	1.4%
Black	48.5%	31.5%
Hispanic	2.6%	3.8%
Other race	2.7%	2.7%
Nonresident	1.1%	1.1%
High School GPA	2.51	2.49
, and the second	(0.59)	(0.72)
High School Graduate	81.6%	82.0%
Full-time	68.8%	76.7%
Placement test score (standardized) ^a	ı	
Math	-0.43	-0.54
	(0.82)	(0.79)
Reading	0.48	-0.41
3	(0.98)	(0.94)
Writing	0.44	-0.44
3	(0.99)	(0.94)
N	3,557	38,224

Note: Standard deviation in parentheses.

information of instructors in our analytical sample. To provide insight on possible differences between instructors teaching online versus face-to-face sections of developmental courses, we present summary statistics separately for instructors who only teach face-to-face sections of developmental coursework and instructors who teach at least one section online. Consistent with the student enrollment by course delivery format, the majority of the instructors teach a fully face-to-face spectrum, where only about 15% of the developmental teaching force offers courses online during the period of this study. These "ever-online" instructors are fairly comparable to face-to-face-only instructors in demographic composition, except for that ever-online instructors are slightly more likely to be Black (15.3% versus 11.2%) and Asian (3.5% versus 1.1%).

In terms of the highest degree attained, however, ever-online instructors on average receive higher degree attainment. Specifically, ever-online instructors are twice as likely to have received a doctorate (15.2% versus 7.7%) and more than one-third less likely to hold a Baccalaureate (18.5% versus 25.1%) as the highest degree. In terms of employment features, ever-online instructors are noticeably more likely to be employed in full-time positions (56% versus 43%) and on average teach more credit each term compared to instructors who only teach face-to-face sections (13.1 versus 9.5). To sum up, these descriptive patterns suggest that online instructors tend to receive higher degree attainment and are more likely to be employed with a full-time contract with an institution. Considering that these individual differences may also contribute to instructors' effectiveness, we control for available instructor characteristics in our preferred model specifications.

^aThe placement test scores are standardized within each college with mean of zero and standard deviation of 1.

⁶Studies that use data from other states also indicate that instructor characteristics account for only a negligible portion of the performance decrement associated with online learning (e.g., Hart et al., 2018).

Table 2. Instructor characteristics by course delivery format.

		Taught only face-to-face
	Taught at least one course online	courses
Female	70.2%	70.3%
Age in 2012	49.0	50.9
	(12.40)	(13.48)
Race		
White	81.3%	86.6%
Black	15.3%	11.2%
Hispanic	0.0%	0.2%
Asian	3.5%	1.1%
Other	0.0%	1.0%
Highest degree attainment		
Bachelor's degree	18.5%	25.1%
Master's degree	66.2%	67.2%
Doctorate	15.2%	7.7%
Full-time employed ^a	56.3%	43.2%
Have other job responsibilities in	47.0%	55.2%
addition to instruction		
Average credit hours/Term	13.1	9.5
	(7.77)	(6.94)
Ever worked in K12 sector	35.8%	48.8%
Total number of dev ed courses	15.6	7.5
taught between 1994 and 2012 ^b	(10.9)	(9.0)
1–3	13.2%	38.8%
4–10	19.2%	32.8%
> 10	67.5%	28.5%
Course section characteristics		
Enrollment size	19.4	18.6
	(8.7)	(9.0)
Average credit hours of the	3.0	3.0
section	(0.24)	(0.36)
N	151	1,046

Note: Standard deviation in parentheses.

Methodology

Addressing ability sorting for current course outcome

Student sorting into the online delivery format

The major challenge in exploring the impact of course delivery formats on student learning outcomes is that some unobserved individual characteristics, such as motivation and ability, may influence both learning outcomes and choice of course delivery format. We are concerned, for example, that the same student who takes a course online rather than face-to-face is likely to have other family or work responsibilities that may negatively influence her course learning outcomes. The descriptive statistics shown in Table 1 suggest that ever-online students are indeed different from students who only take face-to-face courses in a number of ways. To further explore student sorting by course delivery format, we run a

^aFull-time employed defined as worked as full-time instructor during at least half of the terms employed in the institution between 2005 and 2012.

^bWhile our analytical sample only covers student transcript records between 2005 and 2012, the instructor file tracks the instructor-by-term information (such as classes taught in each term) back to 1994, which provides a more accurate estimate of teaching experiences. In all of our regression analyses, we used the instructor file to create an indicator for an instructor's teaching experiences in developmental education course work at the beginning of a given term, measured as the total number of developmental courses taught by the instructor since 1994 and prior to that term.



Table 3. Student sorting into online delivery format.

	Sorting amo	ong students	Sorting within students
Better Subject ^a			-0.0030 (0.0017)
Age upon initial enrollment	-0.0013	-0.0013**	
	(0.0006)	(0.0003)	
Female	0.0021	0.0045**	
	(0.0016)	(0.0015)	
Race (reference group – White)			
Black	-0.0112*	-0.0082**	
	(0.0042)	(0.0030)	
Hispanic	-0.0201**	-0.0184**	
•	(0.0067)	(0.0056)	
Asian	-0.0129*	-0.0122	
	(0.0055)	(0.0070)	
Other	0.0227	0.0029	
	(0.0163)	(0.0043)	
High school GPA	0.0027	-0.0009	
	(0.0027)	(0.0015)	
Earned high school diploma	0.0014	0.0043	
Larried riight serioof diploma	(0.0059)	(0.0029)	
Full-time during first term	-0.0090	-0.0115**	
Tan time daming mot term	(0.0069)	(0.0027)	
Placement test score (standardized)	(0.000)	(0.0027)	
Math	0.0039	0.0016	
Matti	(0.0029)	(0.0013)	
Writing	0.0023)	0.0046**	
witting	(0.0032	(0.0040	
Reading	-0.0007	0.0015)	
heading	(0.0037)	(0.0014)	
Class size	(0.0037) -0.0013	(0.0014) -0.0018*	-0.0012**
Class size			
Course and it house attangues d	(0.0008)	(0.0008)	(0.0004)
Course credit hours attempted	0.0002	-0.0381	-0.0112 (0.0347)
Spring term ^b	(0.0165)	(0.0536)	(0.0247)
Spring term	-0.0055	-0.0055	-0.0236**
	(0.0045)	(0.0046)	(0.0076)
Summer term	0.0156	0.0167	0.0004
6 II - FF	(0.0144)	(0.0129)	(0.0110)
College FE	Yes	Yes	Yes
Student FE			Yes
College-by-course FE		Yes	Yes
Observations	61,831	61,831	61,831
R-squared	0.2603	0.5101	0.8455

Note: Robust standard errors in parentheses: ** p < 0.01, * p < 0.05.

simple regression at the student-by-subject level that uses a student's demographic and precollege academic characteristics to predict whether the student takes her first developmental course in a specific subject online controlling for college-fixed effects.

The results presented in column 1 of Table 3 indicate that online students were less likely to be racial minority students. Once we control for college-by-course fixed effects in column 2 – therefore comparing students who took exactly the same developmental course at the same college – more distinctions between online students and face-to-face students emerged. Specifically, online students were more likely to be females, white students, and students who enroll part time during the first term in college. In terms of prior academic preparedness, online students received significantly higher placement test scores in writing, but comparable scores in the other two subjects. Finally, sections also on average had

^aBetter subject defined as the subject where a student had relatively higher ranking among peers at a college compared with the student's relative ranking in other subjects.

^bReference category is fall term.

slightly smaller class size compared to face-to-face sections. To sum up, online students were older students with slightly better academic preparedness upon college enrollment. This implies that the negative impact of distance learning might be underestimated without controlling for key individual characteristics.

Addressing sorting through a two-way fixed effects model

To address potential problems of student systematic sorting into distance learning, we take advantage of the fact that half of the students in our analytical sample were required to take math, reading, and writing developmental coursework, which allows us to employ an individual fixed effects model to control for any unobserved individual characteristics that were constant within a student. We further combine the individual fixed effects model with college-by-course fixed effects, therefore comparing students enrolled in exactly the same course at a college. More formally, our two-way fixed effects model relates student outcomes i, in section s of course c in subject k at campus j during term t to the delivery format that the student had in her first developmental course in a subject area. It should be noted that "course" is different from "section." Specifically, we use "course" or "collegecourse" to refer to a particular course taught at a specific college, such as Calculus I taught at college A. We use "class" or "section" to refer to a specific section of a course that is uniquely identified by a combination of college, course title, section, and term, such as Calculus I-100 taught by Professor A between 9am and 11am on Thursday in the fall term of 2007.

$$Y_{icstkj} = \alpha + \beta online_{icstkj} + \rho_{ckj} + X_{cstk} + \pi_t + \sigma_i + \mu_{icstkj}$$
 (1)

The key explanatory variable is the course delivery format of the first developmental course a student takes in a specific subject area (online icstkj). ρ_{ckj} represents college-course fixed effects for the developmental course examined, therefore only comparing students who took exactly the same developmental course at a college (such as intermediate algebra at college 101) but enrolled in different sections; X_{cstk} includes information at the course-section level (e.g., number of total enrollments in the course section and the available characteristics of the course instructor). The full list of instructor covariates include individual-level indicators for gender and race, as well as individual-by-term indicators for age at the beginning of a given term, highest degree attained, whether full time employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. It should be noted that while our analytical sample only covers student transcript records between 2005 and 2012, the instructor file tracks the instructor-by-term information (such as classes taught in each term) back to 1994, which provides a more accurate estimate of teaching experiences. In all of our regression analyses, we use the instructor file to create an indicator

⁷For binary outcome measures, we used a linear probability model instead of nonlinear models (such as logit or probit models) due to the methodological challenges associated with the incidental parameters problem with a panel data structure. Specifically, unlike linear regressions that have the property of generating unbiased estimators, logit or probit models generate consistent estimators, meaning that as the ratio of the number of observations to number of parameters increases, the parameter estimates will converge onto their true values as standard errors become arbitrarily small. However, the problem with using non-linear models with panel data - especially when they have a short panel as in the current case – is that the number of parameters grows with the number of observations. That is, we would only have a fixed number of observations to estimate the intercept for each individual and that would not improve when we add additional individuals to the data. As a result, the parameter estimates cannot converge to their true value as the sample size increases, which makes the FE estimator to be inconsistent.

for an instructor's teaching experiences in developmental education coursework at the beginning of a given term, measured as the total number of developmental courses taught by the instructor since 1994 and prior to that term. π_t and σ_i represent fixed effects for the semester of course enrollment and student individual fixed effects respectively.

Addressing ability sorting for gatekeeper course performance

Learning experience in a student's developmental coursework may influence her subsequent gatekeeper course outcomes in at least two ways: whether a student enrolled in a gatekeeper course in the corresponding subject, and the student's grade in the gatekeeper course. One potential threat to estimating the impact on gatekeeper course performance is that a student' developmental course learning experience may also influence students' subsequent choice of the gatekeeper class. Therefore, in quantifying the impact of delivery format of developmental courses on gatekeeper course performance, we use a separate model that further controls for next-class fixed effects:

$$Y_{icskjt+1} = \alpha + \beta Online_{icskjt} + S_{cskjt+1} + \rho_{ckj} + X_{cskjt} + \sigma_i + \mu_{icskjt+1}$$
 (2)

where student i's outcomes in the next class section s in course c in subject k at campus j in time t + 1 to the course delivery format of the first developmental course a student took in a specific subject area (Online icskjt). Since the next course-section fixed effect $S_{cskjt+1}$ is a combination of college, course, time and specific section, this model specification compares student performance in exactly the same next course section taught by the same course instructor. It is worth noting that for gatekeeper enrollment and performance outcomes, we still keep the college-by-developmental-course fixed effects (ρ_{cki}) in the model. This is intended to take care of potential variations in course difficulty between developmental courses within a subject.

Validity of the fixed effects approach

The remaining source of selection after controlling for college-course, student, and term fixed effects is students' differential sorting by delivery format by course subject. We are concerned, for example, that a student was more likely to take a more challenging subject through online format and a less challenging one face-to-face. If that is the case, a negative estimate of distance learning may be partly driven by a student's differential ability across subjects. In a similar vein, students may be more likely to take a class through the face-to-face format in a subject which they attached more value to and also spent more time in that class.

To examine the possibility of differential sorting of course delivery format by subject areas, we compare students' relative ranking in math and writing placement tests respectively and code for the "better subject" where the student had a higher standing among all the students. Column 3 of Table 3 includes an indicator for whether a particular developmental course fell under the subject which a student was better at, controlling for individual fixed effects. The estimate is small in size and is not significant, indicating that while students had general preferences for online versus face-to-face delivery format, such preference was likely to be constant within an individual.

Results

Impact of online learning on developmental course outcomes

Table 4 presents the estimated impact of online delivery format on three developmental course outcomes: (i) whether a student successfully passed a course (versus either failing the course or withdrawing from the course); (ii) whether a student persisted to the end of the course (versus withdrawing after the course add/drop period but before the end of the course); and (iii) course grade among students who persisted until the end of the course. For each outcome measure, we use three different model specifications: a baseline regression that includes available student characteristics presented in Table 1, course-section characteristics (i.e., section enrollment size and credit hours), and term fixed effects; a second model that further includes student fixed effects and college-by-course fixed effects; and finally, our preferred model specification that also controls for available instructor characteristics.

The estimates from our study indicate that taking one's first developmental course online has a negative impact on all three outcome measures and the estimates are robust across all model specifications. Focusing on the estimates based on the preferred specification (column 3, 6, and 9), online delivery format reduces course completion rate by more than 13 percentage (13%) points. This effect is driven by both reduced probability of persisting to the end of the course and performance decrement in course grades. Specifically, students who took the same developmental course online were more likely to withdraw early from the course by 9 percentage (9%) points; among students who persisted to the end of the course, they were subject to a performance decrement by almost 0.3 of a grade point on a 0 to 4 grading scale, which is equivalent to approximately one letter grade down (such as from B+ to B).

Impact on gatekeeper course enrollment and performance

Table 5 presents the estimated impact of online delivery format on subsequent gatekeeper course enrollment and performance, again based on three model specifications. Given the sizable negative impact of online format on developmental course completion, it is unsurprising that students who take their first developmental course online in a subject area were also significantly less likely to successfully enroll and pass the gatekeeper course in that subject. Specifically, taking developmental coursework online was associated with reduced probability of enrolling and passing the corresponding gatekeeper course by 4 percentage (4%) points.

Additional analyses on course enrollment and performance separately indicated that the negative impact of distance learning on gatekeeper course completion was primarily driven by reduced probability of ever embarking on the gatekeeper course: students taking their first developmental course in a subject online were associated with lower probabilities of enrolling in the gatekeeper course in that subject by 7 percentage (7%) points. Considering that the average probability of gatekeeper enrollment among students assigned to developmental programs is 57% in English

Table 4. Impact of delivery format on first developmental course performance.

	(1)	(2)	(3)	(4)	(2)	(9)	<u>(</u>	(8)	(6)
		Pass the Course		Persist	Persist to the end of the Course	Course		Course grade	
Online	-0.1130**	-0.1512**	-0.1349**	-0.0425**	-0.0939**	**0880"	-0.3603**	-0.3356**	-0.2840**
	(0.0284)	(0.0283)	(0.0285)	(0.0149)	(0.0213)	(0.0216)	(0.1012)	(0.0879)	(0.0889)
Z	61,831	61,831	61,831	61,831	61,831	61,831	51,559	51,559	51,559
R-squared	0.1423	0.7425	0.7435	0.0899	0.7134	0.7135	0.2015	0.7945	0.7951
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student FE		Yes	Yes		Yes	Yes		Yes	Yes
College-by-course FE		Yes	Yes		Yes	Yes		Yes	Yes
Student Covariates	Yes			Yes			Yes		
Instructor Covariates			Yes			Yes			Yes
Course Section Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses: ** p < 0.05. Student covariates include all the variables listed in Table 1. Instructor covariates include individual-level indicators for age at the beginning of a given term, highest degree attained, whether full-time employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. Course section covariates include enrollment size and credit hours.

Table 5. Impact of delivery format in developmental coursework on gatekeeper course enrollment and performance.

	-		•						
	(1)	(2)	(3)	(4)	(5)	(9)	(7)	(8)	(6)
	Enroll in a	nd pass gatekeep	er course	Enroll in	_,	ourse	Grade	Grade of gatekeeper co	ourse
Take developmental course online	-0.0415**	-0.0420*	-0.0395*	-0.0654**	-0.0735**	**8690.0-	0.0258	-0.0675	-0.0169
	(0.0116)	(0.0181)	(0.0182)	(0.0191)	(0.0194)	(0.0200)	(0.0586)	(0.1703)	(0.1739)
Z	61,831	61,831	61,831	61,831	61,831	61,831	26,291	26,291	26,291
R-squared	0.1540	0.6975	0.6984	0.2128	0.7507	0.7510	0.1112	0.6914	0.6917
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student FE		Yes	Yes		Yes	Yes		Yes	Yes
College-by-course FE		Yes	Yes		Yes	Yes		Yes	Yes
Student Covariates	Yes			Yes			Yes		
Instructor Covariates			Yes			Yes			Yes
Course Section Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Next-class Section FE								Yes	Yes

Note: Robust standard errors in parentheses: ** p < 0.01, * p < 0.05. Student covariates include all the variables listed in Table 1. Instructor covariates include individual-level indicators for gender and race, as well as individual-by-term indicators for age at the beginning of a given term, highest degree attained, whether full-time employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. Course section covariates include enrollment size and credit hours.



and 31% in math, the 7 percentage (7%)-point average decrease in gatekeeper enrollment represents approximately a 12% to 23% lower probability for gatekeeper enrollment, which is fairly sizable in magnitude.8

Does the effectiveness of online learning improve over time?

With the advancement in technology and system-wide policy changes, the effectiveness of the online delivery format may improve over time relative to face-to-face delivery. To examine this possibility, Appendix Figure A1 estimates the relative impact of different course delivery formats on two outcomes – passing developmental courses and enrolling in gatekeeper courses - separately by cohorts. While the estimates are consistently negative and vary over time, we did not identify any noticeable trend in improvement of online format during the time span of this study (that is, among students enrolled between fall 2005 and spring 2009). We also formally test the possibility of over-time improvement by including time trend into the model and an interaction between the time trend and course mode. The interaction terms are weak and non-significant for both outcome measures.

Discussion and conclusion

Addressing high demand for developmental education and low rates of successful completion with space constraints has been an ongoing challenge for postsecondary institutions. With advances in online instructional technology, online instruction is increasingly considered as a way to alleviate developmental education burdens. Based on a large administrative data from all the public two-year institutions in a state, our study quantified the impact in 2005-2009 of fully online versus traditional face-to-face delivery formats in developmental coursework on developmental education outcomes, as well as on subsequent enrollment and performance in gatekeeper coursework.

Our results indicate that the learning outcomes of developmental education students are substantially compromised when the developmental coursework is delivered online: taking one's developmental coursework online not only negatively influences successful completion of the contemporaneous developmental course, but also results in reduced probability of ever enrolling in gatekeeper courses, which would fundamentally impede students' academic progress. These results therefore have several important implications for online course offering and teaching at community colleges. First, our results are in line with a number of recent studies on distance learning at community colleges that have all identified noticeable online performance decrement (e.g., Hart et al., 2018; Johnson & Mejia, 2014; Kozakowski, 2019; Xu & Jaggars, 2011, 2013). Among these studies, Kozakowski (2019) focused on the impact of course delivery format on developmental students' academic outcomes and is therefore most relevant to our study. Kozakowski found that students who took developmental math through the blended learning format were less likely to pass the course by 10 percentage (10%) points compared with students taking the same course through traditional face-to-face format, which is somewhat similar to the 13 percentage

⁸Studies that use more recent data from other states indicate that the gateway enrollment rates have been fairly comparable across states and over time. For example, based data from students who enrolled in developmental math courses in their first semester between 2008–2009 and 2013–2014 in the Kentucky Community and Technical College System (KCTCS), the author found that the average probability of gatekeeper enrollment in math is 38% (Kozakowski, 2019).

(13%) decrease in course completion we find. While a wide range of factors such as financial constraints and family status may all influence a student's decision to persist in college, negative experiences in these entry-level courses in a student's college career may serve as an important factor in these important decisions.

Additionally, our results also highlight the importance of assisting students in managing their online learning experiences. Existing studies of online learning converge to highlight the importance of self-regulation and online learning self-efficacy in successful online learning experiences (Broadbent & Poon, 2015; Delen & Liew, 2016; Kizilcec, Pérez-Sanagustín, & Maldonado, 2017; Tang & Tseng, 2013; Wang, Shannon, & Ross, 2013). Accordingly, colleges will need to provide sufficient support - such as distance readiness assessments, online learning orientation, and skill scaffolding modules - to help online learners to develop critical skills. At the same time, colleges will need to offer faculty professional development opportunities that inform online instructors of the importance of and specific approaches to scaffolding self-regulation and self-directed learning skills among students in online courses. While a growing number of studies have provided insights into the growth and content of various professional training programs that focus on online instruction (e.g. Bolliger & Martin, 2018; Lee, Pate, & Cozart, 2015; Martin, Sun, & Westine, 2020), little empirical evidence links training in specific instructional practices to actual implemented improvements in instructional practices, or to concrete student course performance and academic progression metrics. This information is critical to designing and delivering effective professional development programs to online instructors.

Finally, given the potential of online learning to provide flexibility to individuals and to address resource constraints faced by institutions, the current online expansion at community colleges is likely to continue and further strengthened as a result of the COVID-19 pandemic. Due to the unstoppable trend of online expansion, it is therefore important for institutions to identify instructional practices and college-provided resources that can be adopted at large to facilitate teaching and learning in a virtual environment. Identifying promising practices that are malleable and are within the control of the institutions and course instructors - rather than demanding more self-directed efforts from students - will allow colleges to implement policies and programs that have the potential to improve the effectiveness of online delivery at scale.

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This study has been determined as "exempt" from IRB review, as it is secondary research of archived de-identified data, where the identity of human subjects cannot readily be ascertained.



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Appendix

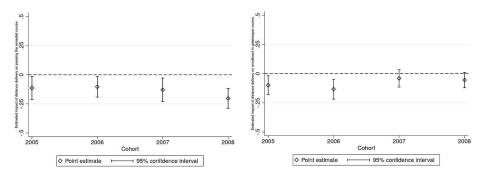


Figure A1. (a) Estimated Effect of Course Delivery Format by Cohort (Outcome: Pass the Developmental Course). (b) Estimated effect of course delivery format by Cohort (outcome: enroll in gatekeeper course in the corresponding subject area).