E-LEARNING RESEARCH

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SHOULD STUDENTS AVOID ONLINE STEM COURSES?

Successful STEM course completion rates online versus face-to-face, after controlling for student self-selection

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Key Takeaways:

After controlling for the specific course taken and student characteristics, including environmental factors (e.g. work and family responsibilities) and non-cognitive factors (e.g. motivation, grit), there was no significant difference in successful STEM course completion rates online versus face-to-face.

Institutions should be cautious in limiting access to online STEM courses through restrictive enrollment or development policies, because this is likely to reduce access to college for non-traditional students (e.g. those with work or family responsibilities) without improving course or college outcomes.

On the other hand, students who do not currently elect to take STEM courses online should not be forced to enroll online, as the results of this study can only be generalized to those students who currently choose to take STEM courses online.

At the same time that online enrollment has increased exponentially over the last decade (Kena et al., 2016), there has been significant—but not always consistent—evidence that students enrolled in online courses may be at increased risk of dropout in comparison to face-to-face peers (Wladis, Hachey, & Conway, 2012; Hachey, Wladis & Conway, 2013). Both in STEM and non-STEM subjects, higher rates of attrition have been documented in online courses (Anderson & Kim, 2006; Morris & Finnegan, 2009; Muse Jr., 2003; Nora & Snyder, 2009; Patterson & McFadden, 2009; Smith & Ferguson, 2005; Summers, 2003). However, it remains unclear the extent to which this gap may be due to features of the online environment itself versus the characteristics of students who self-select into online courses (Aragon & Johnson, 2008; Xu & Jaggars, 2013). Furthermore, there are currently conflicting results about whether students who enroll in online courses have worse subsequent college outcomes; several large-scale studies report negative outcomes (Conway, Hachey, & Wladis, 2014; Jaggars & Xu, 2010; Xu & Jaggars, 2011a; Xu & Jaggars, 2011b; Xu & Jaggars, 2013) and some report positive outcomes (Johnson & Mejia, 2014; Shea & Bidjerano, 2014). These mixed findings maybe due to a lack of a wide range of controls for student self-selection in online learning, including environmental and non-cognitive factors.

This research brief summarizes results presented in more detail in the following paper(s):
Wladis, C., Hachey, A. C. and Conway, K. M. Do students who take online STEM courses have worse outcomes? Comparing matched students in online versus face-to-face course sections. *Manuscript submitted for publication.*

Comparing online versus face-to-face outcomes for STEM courses specifically is a relatively unexplored area. The few small studies that have compared students in a variety of online STEM courses to students in a matched face-to-face course (Ashby, Sadera & McNary, 2011; Enriquez, 2010; Plumb & LaMere, 2011; Werhner, 2010) offer mixed results: some report higher attrition in online sections, some found no difference, and some found that weaker students tended to withdraw online but tended to fail or earn a "D" in the course face-to-face. An issue with these studies is that they all had very small sample sizes, did not control for instructor and course type, and did not address the potential impact of student characteristics. Two large-scale studies also included online mathematics courses, comparing outcomes for students who took online courses at community and technical colleges in Virginia and Washington State (Jaggars & Xu, 2010; Xu & Jaggars, 2011a; Xu & Jaggars, 2011b). Results from these studies indicate that students who enrolled in online courses during their first few semesters were more likely to drop out or earn an "F" grade and slightly less likely to persist in college, even when statistical techniques were used to control for several student factors. However, these studies focused on general course patterns for Math and English specifically (thus, not accounting for a wide range of STEM courses), and since they utilized only institutional research data, they also did not control for a wide array of student factors.

Previously, using a decade of multi-course data from the third largest community college in the U.S., we investigated the relationship between course and student-level factors and online STEM course outcomes. This study revealed an increased risk of dropping out when moving from a face-to-face to online environment for community college students in STEM courses in comparison to non-STEM courses (Wladis, Hachey & Conway, 2013). Results also indicated significant differences in success rates between STEM career and STEM elective courses. However, after controlling for student characteristics, differences in course outcomes by course characteristics became insignificant; this suggests that it may be the characteristics of students who chose to take these courses online that influence why certain types of STEM courses were shown to be higher/lower risk in the online environment (Wladis, Hachey, & Conway, 2014a).

In other studies, we previously found a number of patterns that identify which groups of students may be at highest risk in the online STEM environment. We found that prior online success or failure was significantly predictive of future online STEM course success or failure, above and beyond GPA itself (Hachey, Wladis, & Conway, 2014). Additionally, we found that older community college students did significantly better in online STEM courses and women did significantly worse (although still no worse than men) than would be expected given their outcomes in face-to-face courses. Results also indicated that there was no significant interaction between online learning and ethnicity; thus, while Black and Hispanic students did on average have worse outcomes than their White and Asian peers in both online and face-to-face STEM courses, there was no increase in this gap in the online environment (Wladis et al., 2015b).

All of the studies noted above investigating STEM online learning attempted to control for student characteristics in some way. However, they also utilized only institutional research [IR] data and therefore, were not able to control for a broad range of environmental and non-cognitive factors, since these factors are not routinely gathered in IR datasets. In actuality, almost all prior research on online course outcomes (both generally and in STEM specifically) have excluded important non-cognitive and environmental factors due to limitations in the availability of data; for example, while many students cite family responsibility as a reason for enrolling in online courses, no prior studies aside from Wladis, Conway & Hachey (2016) have included information about the age and/or number of dependent children as a control variable when comparing online versus face-to-face outcomes. The study reported here addresses this issue by utilizing systematic surveys of students in matched sets of online and face-to-face STEM classes and merging those responses with institutional research data in order to account for a wider range of potentially influencing factors than has been controlled for in previous students on online STEM classes.

Methods

This research used an initial sample frame (called the *IR dataset*) of all students enrolled in the City University of New York (CUNY) for all courses in which at least one section was offered either partially or fully online in fall 2014 (including students who took face-to-face sections of these courses). Students were emailed a link to an online survey (we call the subset of students who responded to the survey the *survey dataset*). The survey utilized scales which measure several different affective and "life" factors: motivation; course enjoyment/engagement; academic integration; self-directed learning skills; time management skills; preference for autonomy; and grit (i.e. perseverance/passion for long-term goals).

To control for course diversity, both the *IR* and *survey datasets* were further reduced to include only those students who took STEM courses for which both fully online and either hybrid or face-to-face course sections were available. The resulting *IR dataset* had a sample size of 44,502 and the *survey dataset* had a size of 2,005. Matched samples were then generated for each data set, with sample sizes of 3,396 for the resulting *matched IR dataset* and 278 for the resulting *matched survey dataset*. *Successful course completion* was measured as a grade of "C –" or higher (because it is the typical standard to receive major or transfer credit). Course medium was dichotomized to not-fully online (hybrid or face-to-face) or fully online (80% or more content online), based on Sloan Consortium definitions (Allen & Seaman, 2010). Xu & Jaggars (2011a/b) report that students who take hybrid courses (33-80% online content) share similar characteristics with students who take face-to-face courses and that their outcomes are similar; preliminary tests with this data confirmed this pattern. Missing responses on the survey were imputed using multiple imputation and the survey dataset was weighted to account for survey non-response and to ensure that the weighted survey dataset was representative of the sample frame from which it was drawn. Using several different statistical modeling approaches, this study analyzed the relationship between online enrollment and course outcomes while attempting to control for both student characteristics and the exact course taken online versus face-to-face.

Results and Discussion

The results of this study found that on average, students who took STEM courses online were at no higher risk of dropping, failing, or earning a "D" grade in a course than comparable students who took the same course face-to-face. This suggests that patterns that we have previously found for all courses [both STEM and non-STEM] (Wladis, Conway & Hachey, 2016) also appear to hold for STEM courses specifically.

Figures 1-4 depict the odds ratios with error bars representing the 95% confidence interval, for each model run on each dataset. Odds ratios greater than one show that students were more likely to successfully complete an online than a face-to-face course, whereas odds ratios less than one show that students were less likely to successfully complete the course online. Odds ratios equal to one (or, equivalently, whose error bars include one) show no difference in rates of successful course completion between mediums.

Figures 1 and 2, which depict the IR dataset where environmental and non-cognitive variables could not be controlled, show the following patterns: with no controls, online students have higher rates of successful course completion, but after controlling for specific course taken, this relationship reverses, revealing a small but significant negative effect of online enrollment on course outcomes (Figure 1); however, after matching on a wide array of student characteristics, these differences disappear and we see no significant difference between online and face-to-face course outcomes (Figure 2).

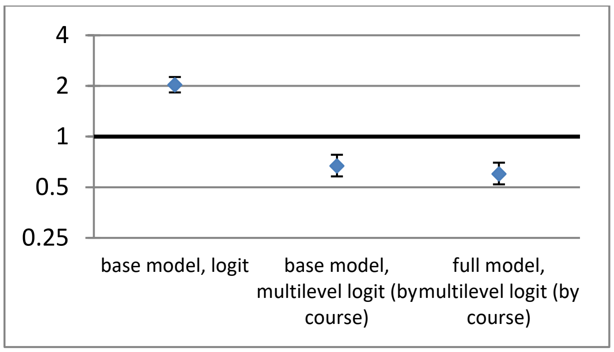

Figure 1. Models with various levels of student- and course-level controls on the IR unmatched dataset.

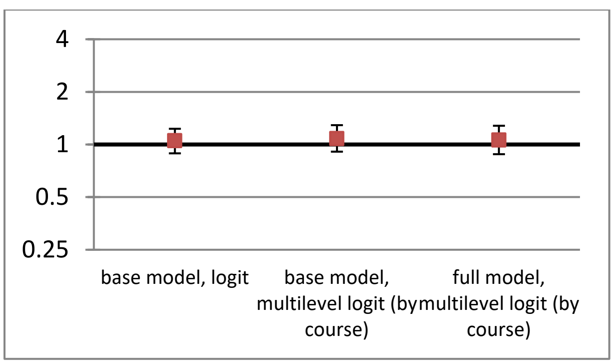

Figure 2. Models with various levels of student- and course-level controls on the IR matched dataset.

In Figures 3-4, which depict the survey dataset where environmental and non-cognitive variables are included, we see somewhat similar patterns, in which students in STEM courses do better online than their face-to-face counterparts on average before controls for specific course taken or matching on student characteristics, but there is no significant difference in online versus face-to-face STEM course outcomes after controlling for and/or matching on specific course taken, various demographic and academic variables, as well as environmental and affective factors.

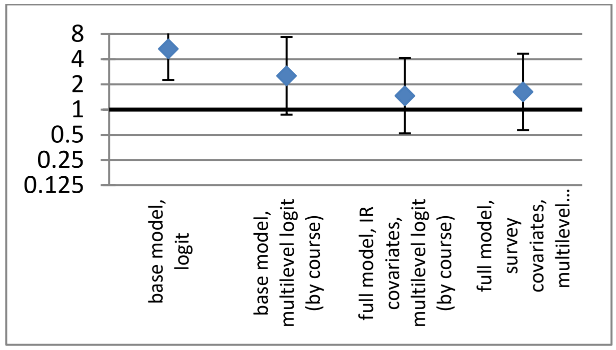

Figure 3. Models with various levels of student- and course-level controls on the survey unmatched dataset.

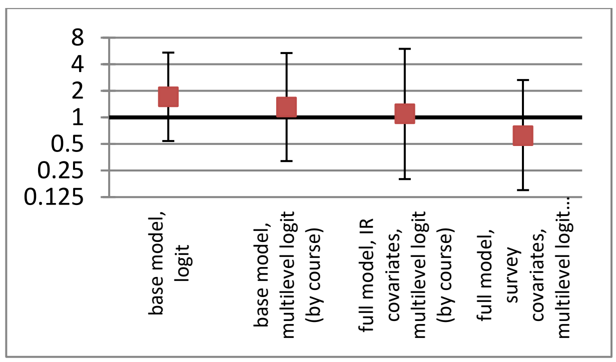

Figure 4. Models with various levels of student- and course-level controls on the survey matched dataset.

We also use sensitivity analysis to assess how sensitive our result (that taking a STEM course online does *not* increase the risk of failure/D grades/dropout) might be to hidden bias from unmeasured variables not included in our study. This type of analysis tells us how strongly an excluded variable (that was not a part of this analysis) would need to influence student likelihood of enrolling online (while simultaneously significantly increasing the likelihood of dropping/earning a D/failing the course) in order to negate the results of this study.

Using Rosenbaum's method (Rosenbaum, 2002) to perform sensitivity analysis (for $\alpha=0.05$) showed that: taking a STEM course online could significantly decrease the chance of successful course completion if there are unobserved factors that significantly decrease the likelihood of successful course completion while simultaneously increasing the likelihood of fully online course enrollment by 24%. (On the other hand, enrolling in a STEM course online could significantly *increase* the likelihood of successful course completion if unobserved factors significantly increase the likelihood of successful course completion while simultaneously increasing the likelihood of fully online course enrollment by 10%).

The survey results are even less sensitive to hidden bias, with a very high upward hidden bias threshold: taking a STEM course online would significantly decrease the chance of successful course completion if there are unobserved factors that significantly decrease the likelihood of successful course completion and simultaneously more than triple (increase by 330%) the likelihood of fully online course enrollment. (On the other hand, enrolling in a STEM course online could significantly *increase* the likelihood of successful course completion if unobserved factors significantly increase the likelihood of successful course completion while simultaneously increasing the likelihood of fully online course enrollment by 62%).

Findings from this study suggest that taking a STEM course online instead of face-to-face does not on average decrease students' likelihood of successfully completing the course.

Implications

Despite concerns raised in previous studies, the results of this study indicate that institutions should be wary of restricting student access to online STEM courses sections. Based on our findings, policies that seek to screen STEM students, that limit STEM online enrollment to certain student groups (e.g. GPA requirements), that limit the number of STEM courses that students can take online, that restrict which STEM courses can be offered online, or that limit the number of STEM online courses that faculty can teach, may unnecessarily restrict student access to STEM courses without actually improving STEM course outcomes.

However, we only considered population-average effects for students currently enrolled in STEM online courses, thus the findings from this study may not generalize to all student groups; it is possible that the relationship between online course enrollment and subsequent outcomes may vary for different types of students. Therefore, it is important to note that the patterns observed cannot necessarily be applied to specific sub-groups (such as community college students, or ethnic minority students in less diverse samples) or to students who are currently not enrolled in online courses and who may be very dissimilar from those students who currently enroll in online courses. While our findings indicate that enrolling in online STEM courses did not result in negative outcomes for students who choose to enroll online in comparison to their face-to-face peers, it cannot be inferred from this study that requiring all students to take online courses would have no negative outcomes. Therefore, policy makers should still be cautious about compelling students to take STEM courses online (e.g. by requiring STEM online course enrollment, or by providing insufficient face-to-face STEM course sections to meet student demand).

Similarly, it is important to note that these results are not generalizable to all types of online courses. The patterns observed in this study apply only to traditional, semester-long online STEM courses taught by university faculty that are meant to be comparable to face-to-face course sections (e.g. in terms of time student/faculty time commitment, incentives for completion, and level of instructor interaction). Thus, the findings cannot be extended to other types of online courses such as MOOCs; self-directed STEM learning modules provided by publishers or other organizations; or STEM online courses taught by off-site instructors not affiliated with a non-profit college institution. These other types of online STEM courses may in fact have lower passing or retention rates than comparable face-to-face courses, and further research is needed before any conclusions can be drawn about the potential risks of enrolling in these types of online STEM courses.

Acknowledgments

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