Evaluating Access, Quality, and Inverted Admissions in MOOC-Based Blended Degree
Pathways: A Study of the MIT Supply Chain Management MicroMasters

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Abstract

Many higher education institutions have begun offering opportunities to earn credit for in-person courses through massive open online courses (MOOCs). This mixed-methods study examines the experiences of students participating in one of the first iterations of this trend: a blended professional master's degree program that admitted students based on performance in MOOC-based online courses. We found that the blended master's program attracted a cohort of highly educated mid-career professionals from developed countries who were looking for more flexible alternatives to traditional graduate programs. Success in the online courses was correlated with higher levels of prior formal education and effective use of learning strategies. Students who enrolled in the blended graduate program reported being academically prepared for their coursework and had higher GPAs (3.86, $p < 0.01$) than students in the residential program (3.75). The findings of this study suggest that the technological affordances of MOOC-based online and blended degrees will neither transform higher education nor solve its most stubborn equity challenges, but there may be particular niches where they provide a valuable service to learners in particular programs and contexts.

Keywords: online learning, professional education, MOOCs, access, admissions

Introduction

Massive open online courses (MOOCs) gained popularity in the early 2010s, as universities began offering free online courses which attracted hundreds of thousands of learners (DeBoer, Ho, Stump, & Brelow 2014; Perna et al., 2014). Developers of MOOC platforms promised to transform higher education by creating new global on-ramps into higher education in places poorly served by traditional higher education systems (McPherson & Bacow, 2015). In the past few years, the field has shifted to emphasizing fee-based professional credentials, credit-bearing courses, and degree programs through MOOCs (Caudill, 2017; Ingolfssdottir, 2016; Joyner, 2018). Though a few voices continue to promise disruptive change in higher education through online learning (Christensen, 2017), it appears likely that MOOCs will be integrated into existing higher education systems rather than delivering transformational change (Al-Imarah & Shields, 2018)

This study examines the experiences of students in one of the first blended MOOC-based degree programs, a professional master's program in supply chain management (SCM) offered by the Center for Transportation and Logistics at the Massachusetts Institute of Technology (MIT)¹. Supply chain management is a rapidly growing field of study concerning of logistics and operations within increasingly global supply chains (McCrea, 2016). The program offered a non-degree credential, called a MicroMasters, through MOOCs on the edX platform. To earn a MicroMasters, students needed to pay for and complete five MOOCs and pass a proctored exam. Students who earned the MicroMasters were eligible to apply for a one-semester residential master's degree program, without having to submit standardized test scores or undergraduate grades.

In this study, we track the first cohort of students to participate in the MicroMasters and the blended degree program, from their online courses through their one semester of residential courses. The image in Figure 1 describes the number of students who completed each step in the process; what is known in the MOOC literature as the “funnel of participation” (Clow, 2013). As of May 2017, when applications were due for the blended program, over 80,000 students had participated in at least one of the supply chain management MOOCs, and 622 of them had earned a MicroMasters. In January 2018, the first cohort of 40 blended students arrived on MIT’s campus joining a cohort of 42 residential students in a traditional full-year supply chain management master’s program. Both cohorts completed the program in June 2018. All 82 students participated in January-term courses together, and then took a class all together in the spring semester, alongside additional, individually-chosen elective courses.

[Insert Figure 1 Here]

Background

The Evolution of MOOCs: From Teaching the World to Online and Blended Professional Master’s Degrees

MOOC advocates originally described their efforts as a way to expand opportunity by offering free, online classes from elite U.S. institutions such as Stanford, MIT, and Harvard at a large scale (Perna et al., 2014). The original MOOC business model was a “blue ocean” strategy; designing products for new, untapped markets rather than competing in existing ones (Chan Kim & Mauborgne, 2005). MOOC providers imagined a global market of potential

learners with limited access to higher education who would be willing to pay a small fee for a verified certificate from online courses. But this market never materialized; for instance, HarvardX and MITx awarded over 53,000 certificates in the 2016 academic year but only 28,000 and 19,000 in each of the subsequent two academic years (Authors, Under Review). Rather than generating the exponential growth needed to sustain a “disruptive” strategy, the certificate consumer base grew modestly and began to decline.

In response to this changing landscape, MOOC providers have moved from a “blue ocean” strategy to competing directly with existing online program providers for university dollars. For many years, universities have outsourced creating new online programs to for-profit Online Program Managers (OPMs) who are put in charge of marketing, online infrastructure, instructional design and even instruction and assessment (Mattes, 2017). OPMs usually invest the capital to create the courses upfront in exchange for an ongoing share of tuition revenue (McKenzie, 2018). OPMs are now a multi-billion dollar industry with large for-profit education companies such as Pearson, Wiley, and 2U offering these services to universities (Hill, 2018). MOOCs providers such as Udacity, Coursera, and edX are now competing directly against these established OPMs with executive education and online degree programs (Young, 2018).

Although MOOCs are relatively new to this field, there is some historical precedent for OPM-like arrangement between MOOC providers and universities. In 2014, Georgia Tech and Udacity offered the first MOOC-based online master's degree in Computer Science, which was designed to emulate the in-person program at one-sixth of the cost (Goodman, Melkers, & Pallais, 2016). Goodman et al. (2016) found causal evidence that the program increased enrollment among older students who otherwise would have been unlikely to enroll in a computer science master's degree program. Another relevant example is Arizona State

University's Global Freshman Academy where students take introductory undergraduate courses online through edX and, if they pass the courses, they can apply their online courses towards in-person credit at Arizona State or at another institution (Ehrenberg, 2015).

One advantage that MOOCs providers have over existing OPMs are the associations with elite institutions. Most OPM arrangements tend to be hidden from public view (Mattes, 2017), but universities can openly associate with edX or Coursera. This openness also provides opportunities for more types of blended degree programs, where students complete some learning online and then apply to accelerated residential degree programs (Caudill, 2017; Ingolfssdottir, 2016). Additionally, MOOC-based degrees promise to reduce tuition costs by automating faculty labor through recorded lectures and auto-graded assessments, while maintaining quality by drawing content from elite institutions. In theory, reduced costs might then make these online and blended forms of higher education more accessible to diverse populations.

However, the initial research on MOOCs offers cautionary notes about both instructional quality and accessibility. MOOCs have been criticized for weak pedagogical practices and student supports, such that only students who come to courses with well-developed self-regulated learning strategies--goal-setting, strategic planning, and monitoring -- will be successful (Kizilcec, Pérez-Sanagustín, & Maldonado, 2017; Littlejohn, Hood, Milligan, & Mustain, 2016). Students who do well in this format are more likely to have higher levels of education and wealth (Hansen & Reich, 2015; Kizilcec, Saltarelli, Reich, & Cohen, 2017). Moreover, revenue-seeking and expanding opportunity can be misaligned incentives for institutions considering online courses. Research on existing OPMs has found that external providers are incentivized to prioritize revenue and enrollment maximization over instructional

quality and student support (Mattes, 2017; Russell, 2010). As MOOC providers pivot to serving as OPMs, they will likely face similar pressures.

MicroMasters: Program Design Hypotheses for a “Stackable Credential”

In this broader policy context, edX and MIT experimented with a new approach to blended learning: a MicroMasters and associated blended master's degree in supply chain management (SCM). To earn the MicroMasters, students must pay for and complete a series of related MOOCs on a topic and pass a proctored assessment. These credentials are intended to be “stackable”; students can use the MicroMasters as a stand-alone credential or they can apply the MicroMasters toward course credit and advanced standing in the residential degree program at MIT or to other graduate degree programs that allow students to transfer credits from the MicroMasters (Young, 2018). Students are admitted to the MIT residential program largely based on their performance in the MOOCs and are not required to submit standardized test scores or undergraduate grades. The admissions process is “inverted” as potential applicants must demonstrate proficiency through the online course before they are officially admitted to the program. MIT faculty and staff developed the content and designed the courses, while edX was responsible for marketing and technical infrastructure.

We identified three design hypotheses informing the development of MicroMasters and MOOC-based blended master's degree programs. First, online courses can provide valuable learning experiences at low marginal costs. Ideally, program designers can identify learning experiences that are better suited for online study —declarative knowledge, quantitative or computations operations, introductory materials —and include those in the online courses. Other learning experiences--projects, case studies, collaborative group work, capstone experiences--can

be reserved for on-campus classes. Second, through “inverted admissions”, students can be selected on the basis of demonstrated interest and competency in the field, instead of evaluating academic competence through grades and standardized tests. Third, these pathways can attract new types of students who otherwise would not have pursued a degree or credential through a higher education institution. By offering a lower price point, making courses accessible online, and offering an inverted admissions process for in-person learning, MOOC-based degree pathways may potentially attract a more socio-economically and internationally diverse cohort of students.

Research Questions

In this study, we explore these design hypotheses within the first cohort of the MIT Supply Chain Management MicroMasters and associated blended master’s degree program. We will address five related research questions related to participants’ background characteristics, experiences in the online courses, and admission and experiences in the residential program.

1. What types of learners participated in the online SCM MicroMasters, and how did learners engage with the online courses?
2. How did successful learners perceive the quality of the online learning experience within the online courses?
3. What characteristics or learning practices distinguished learners who persisted through the MicroMasters program?

4. Did this “inverted admissions” process for filtering potential applicants to the blended master's degree program select different types of candidates than the residential graduate admissions processes?
5. What were the experiences for students who attended the blended professional master's program and how do they compare to the experiences of students in the traditional residential graduate programs?

Methods Summary

Study Setting

The MicroMasters and accelerated blended master's in supply chain Management (SCM) was offered through MIT's Center for Transportation and Logistics (CTL). Founded in 1973, the CTL conducts research and consulting related to logistics and operations management, and offers master's degrees, doctoral degrees, and executive education programs.

Supply chain management is a rapidly growing field with global demand from large multinational companies like Apple and Amazon, and regional providers of warehousing, packaging, transportation, and related services. The field encompasses technical skills, such as forecasting and operations research, with management skills, such as business strategy. However, few business degree programs currently offer specializations in all aspects of the supply chain (McCrea, 2016). As a field with growing educational demand that is currently underserved by higher education institutions, new online and blended pathways may be well positioned to bridge this gap.

Data Sources and Analysis

This study used an iterative, integrated mixed-methods approach to data collection and analysis (Greene & Caracelli, 1997; Teddlie & Tashakkori, 2006). To address our research questions about students' experience in the online courses, we used data from edX such as entrance surveys and the tracking log data from the online platform. To understand students' online learning behaviors, we examined indicators that prior work suggests are correlated with success in online learning: time in course, participation in community forums, revisiting previously watched lectures, and revisiting previously completed problems (Kizilcec et al., 2017; Perry & Winnie, 2006). We present descriptive statistics below, with more methodological details in the supplementary materials.

To more deeply understand students' online learning experiences and admissions processes and decisions, we interviewed students in both the blended ($N = 33$ students; 85% response rate) and residential cohorts ($N = 18$ students; 45% response rate). We interviewed students in January of 2018 after the first semester for residential students and right after the blended students arrived. For the interview coding, we used a grounded theory approach (Glaser & Strauss, 1967) with open coding using a constant comparative approach (Boeije, Duijnste, Grypdonck, & Pool, 2002; Glaser & Strauss, 1967).

To investigate student experience and learning during the on-campus semester, we conducted follow-up interviews with nine students from the blended cohort, administered an end-of-semester survey to both cohorts ($N = 68$; 83% response rate), and examined students' final course grades.

Our study describes a single cohort from one MicroMasters program, and our findings will not generalize to all other MOOC-based online and blended programs. While we have survey responses and log data from all types of online participants, we only interviewed students who enrolled into the blended program. Our qualitative data for this study only describes the online courses from the perspective of a subset of very successful students, much more could likely be learned from a wider range of online participants.

Findings

MicroMasters Participants Were Mid-Career Professionals with Previous Formal Education Experience

The online supply chain management courses that made up the MicroMasters program attracted a population of learners very similar to those found in other STEM MOOCs and MOOCs from technical professions. In Table 1, we show the age, gender, country of origin, and level of education of five types of participants in the MicroMaster courses, as well as the 2017-2018 full-year residential cohort of the SCM master's degree. Like many STEM MOOCs, typical participants were mid-career, male, from countries around the world, and already educated (Chuang & Ho, 2016). The cohort of participants who earned the MicroMasters credential was more likely to be male, from more affluent countries, and to have a master's degree than non-completers. When comparing the blended masters' students to the residential students, the blended students were older, had more work experience, and were substantially more likely to already have a master's degree.

[Insert Table 1 Here]

Although most MicroMasters participants were highly educated professionals, there were students who completed the MicroMasters who did not fit the profile of students who traditionally enrolled in the residential graduate program. For example, 4% of students who completed the MicroMasters did not have a Bachelor's degree. Additionally, 6% of MicroMasters participants were age 50 or older when they earned the credential and 3% were under 25 years old.

Some non-traditional MicroMasters participants enrolled in the blended program. In interviews, a number of blended participants described backgrounds that did not fit the profile of traditional students in the residential program. One student had worked in humanitarian logistics prior to coming to the program, coordinating relief efforts in war and disaster zones; another student had dropped out of college twenty years earlier and was only now returning to higher education.

MicroMasters Completers Sought High Quality Job-Relevant Content

MicroMasters completers reported that they enrolled in the courses because they were interested in course content and were looking for ways to advance their careers. Across all entrance surveys, 87% of students who completed the MicroMasters said “learning about course content” and 83% said “advancing my career” was a very or extremely important reason for taking the courses. The majority of MicroMasters completers (87%) were working full-time while they completed the online courses.

We found similar trends in our interviews with participants in the blended programs. Participants described the job-relevant content of the courses as one major factor in drawing them into the courses. Several participants described how the courses provided a formal introduction that explained and defined common work experiences. As one student explained, "Sometimes at work there are things that you realize on your own. But then when I was doing the course, it turns out this thing had a name, you know? This was the most appealing thing to me". Of the blended students interviewed, 84% said they found that the course helped them in their job performance and many shared examples of how they were able to apply what they learned in their work.

Although we did not interview students who did not enroll in the blended program, one piece of evidence that other MicroMasters students found the content of the courses valuable is the percentage of students who paid for multiple courses. We found that among all MicroMasters students who completed at least one course, 84% paid the verification fee for at least one other course in the MicroMasters.

Persisting through the MicroMasters with Self-Regulated Learning

Completing the online courses required a significant time commitment from students. Students who completed the MicroMasters spent an average of 157 hours on the edX platform over 287 days (an average of about 33 minutes a day). This does not include any potential time spent outside the edX platform working on the courses. In our interviews with students in the blended program, one recurring theme was how students juggled their schedules in order to make time for completing the courses. Students scheduled time for course content around their work

lives— waking up early, working during lunch, or working late into the evening. One student described his experience in the online course this way:

That was very, very tough. I work a lot. I work sometimes I would say 60 hours a week....And I was doing the online courses between 1:00 and 3:00 AM in the morning so that was very tiring and a lot of tea to keep going like that.

Students use of self-regulated learning strategies within the online courses were also correlated with success in the MicroMasters. Table 2 displays course-level averages for self-regulated learning behaviors by students' level of completion of the program, excluding auditors who may not have intended to complete the courses. Compared to students who paid the verification fee but did not complete a course, students who completed the MicroMasters spent more time in the course and were more likely to post in the course forums. Additionally, they were more likely to revisit previously watched videos and problems they had previously answered corrected, perhaps reflecting participants engaging in retrieval practices — testing their knowledge as they learned (Karpicke & Roediger, 2008; Kizilcec et al., 2017).

[Insert Table 1 Here]

In interviews with blended students, participants described using self-regulated strategies in their learning. For example, one student described an instance of “metacognitive monitoring” (Zimmerman, 2008) where he recognized that his approach to learning wasn’t working and decided to switch tactics mid-way through the MicroMasters:

So I think the first one, SC1x was the first course that I did, and I didn't really do that well. I think I was just trying to figure out how to manage...But I think by the latter part of SC1x, I had my strategy pretty good. Every week, I would... The moment the next material is released, I just print out everything in a booklet format, which I used to keep with me. And in my rides to the office, I used to just skim through it.

In summary, the typical MicroMasters completer had already earned a master's degree and worked full-time in a logistics capacity, and they used the SCM online courses to deepen their understanding of their professional field. They found their online learning experiences immediately relevant to their work context, and they showed high levels of self-regulated learning behaviors: spending many hours online per course, participating in forums, and revisiting lectures and assessments. In the next sections, we describe how the cohort of 40 blended students transitioned from the MicroMasters to the blended program and their experiences once they arrived at the on-campus program.

Inverted Admissions Process Attracted Different Types of Students Than Traditional Residential Admissions

Of the 622 participants who earned a MicroMasters credential, 130 applied to MIT's accelerated one-semester blended Master's degree program in Supply Chain Management. Admission was a holistic process; students were required to submit letters of recommendation and write essays. However it differed from the standard admissions process in two key ways: 1) instead of considering GPA, transcripts, and standardized test scores SCM faculty who were

reviewing applications used scores from the online courses and 2) only students who completed the MicroMasters were eligible to apply to the blended program.

This inverted admission process led to several important differences in the blended cohort. First, most admitted blended students only applied to MIT. Compared with residential students, 71% of whom reported considering other graduate programs, only 6% of blended students said they had other considered other graduate degree programs. The prestige of the graduate program combined with the fact that there would be an alternative admissions track motivated many to complete the MicroMasters in order to apply for the degree program. One student reflected on the admissions process:

They're looking for the inverted admissions through the MicroMasters to the proper degree program. And then it became like, okay. So this is more a decision point, this looks like this course is turning towards a degree.

Residential students often planned to use the degree as a career steppingstone, while blended students often planned to remain in their current roles. Seventy-one percent of blended students interviewed said they had the option to go back to their previous position compared to only 13% of residential students.

Blended Students Felt Academically Prepared for In-Person Courses and Valued Experiences On-Campus

The blended master's students arrived on campus for the January term and graduated at the end of the spring semester. The blended students took one required course together with the

full-year residential master's degree students, and then they took at least three elective courses, including a capstone or thesis course.

Blended students reported that they felt highly prepared for their in-person courses. In the end-of-semester surveys 100% of blended students “agreed” or “strongly agreed” that they felt academically prepared for the courses in their program (Figure 2). In interviews, blended students described the online classes as potentially superior to residential classes. For example, when they were learning technical concepts, they were able to review material immediately. One student made the following observation:

So some of the concepts that were presented online were a lot more technical and maybe difficult to grasp immediately, especially for some people, being able to rewind, redo it, having the quick feedback from the practice questions, things like that. I think in a more traditional residential classroom setting would be difficult.

That said, blended students described the residential program as adding value to their online learning experiences. Interviewees particularly appreciated the ability to work on complex problems with other students which they felt would be difficult to replicate in an online environment. One blended student reported the following experience:

I think in online courses, there's always a right answer. And that does not mean it's easier, but it's more structured and it's intended to guide us through to the single answer. Whereas here, it's a lot more open-ended, which is a lot more interesting, but it requires you to actually think of a lot more complicated stuff.

Blended students also described interactions with other students during the classes as being an important part of their on-campus learning experiences. On the end-of-semester survey, 66% of blended students said they learned from teamwork in SCM courses and 84% of students agreed or strongly agreed that other students positively influenced their intellectual growth (Figure 2).

[Insert Figure 2 Here]

One blended student described the benefits of learning in-person this way:

I think one of the greatest benefits I found is you see other people's thought process in the way they're tackling a problem, it really gives you an opportunity to think like, "Hey, I didn't think of that," or, "Oh, I can add something that I think will help in class."

In the end-of-semester survey, blended students reported feeling similarly high levels to residential students of belonging to the institution as residential students, seeing themselves as part of the larger institutional community, and believing they made the right decision to attend the university (Figure 2). For many blended students, the sense of connection to the institution began when they were taking the online classes, even before they formally enrolled in the graduate program. In interviews, one student described feeling like they were part of an existing community when they were still taking the online MicroMasters classes:

The same names pop up. The same names answer questions. We have a LinkedIn group that's kinda separate from the MIT one. We start emailing each other. We have a WhatsApp group as well and things like that. Yeah, when I came here... a lot of the names were already familiar.

Blended Students Performed Well in In-Person Courses

Blended students did well in their in-person courses. Blended students' had a slightly higher GPA in their spring semester courses than residential students ($p < 0.01$) and students from outside the program who were in the same classes ($p < 0.001$) (Figure 3). This difference continued to hold even when we adjusted for students' course selection (see supplementary materials for a taxonomy of model specifications).

[Insert Figure 3 Here]

Discussion

At the beginning of this article we outlined three design hypothesis that motivated the development of the MOOC-based online and blended degree pathways: (1) online learning experiences can reduce tuition costs and opportunity costs by providing high-quality, largely self-paced content, (2) performance in online courses can provide an admissions selection mechanism at least as good as standardized tests performance or previous grades, and (3) online models can improve equity in access to educational experiences both through decreasing the price of education and identifying qualified candidates through online courses. In our study of the supply chain management MicroMasters and blended master's degree, we found some evidence to support the first and second hypotheses. Students described the content of the courses as high-quality and job-relevant and many found that the affordances of online learning helped them understand the content. Students admitted into the blended program reported being academically prepared by the online courses for their in-person learning experiences.

This initial case study also suggests that inverted admissions through MOOC-based blended program can be an effective way of recruiting highly-qualified applicants to professional master's programs. Blended students performed slightly better in their in-person courses than

students in comparable residential programs. Through their learning in the MicroMasters, blended students demonstrated a mastery of course content and self-regulated learning skills. They also developed a sense of community and belonging in the MicroMasters that persisted through the on-campus courses.

We did not find evidence for the third hypothesis, that moving learning online will make educational opportunities more equitable. The cohort of individuals who completed the MicroMasters was composed of mostly highly educated students from advanced developed countries. Although we did identify some outliers, such as people without undergraduate degrees or over the age of 50, the MicroMasters seemed to serve individuals who were largely well-served by traditional educational institutions. Previous scholars have observed although MOOCs are in theory open to anyone to access, students with higher levels of experience with education and more well-developed self-regulated learning strategies are more likely to be successful in these formats (Littlejohn & Hood, 2018)

As other authors have noted (i.e., Linn, 1990; Mattern, Sanchez, & Ndum, 2017) admission measures often screen candidates on selection mechanisms that are imperfectly related to educational goals and can result in inequitable outcomes for certain groups. Switching from admissions tests and undergraduates grades to performance in online MOOCs changed the selection mechanism but did not necessarily make it more equitable. Our findings suggest that a MOOC-based inverted admissions program screens people on their ability to persist through largely independent, asynchronous, online learning experiences. Although this process can produce highly qualified applicants, as our findings demonstrate, the process screens out potential students who might struggle to learn in an online setting: even though online learning skills are not a prerequisite to success in the fields of logistics and operations.

This case study of a successful launch of a MicroMasters program can offer some guidance to universities considering similar MOOC-based programs. A major reason students reported persisting through the program was on account of the job-relevance of the online content; the learning experience was perceived as being immediately relevant in their professional work. Importantly, students perceived the content of the supply chain management courses, definitions in a new field, declarative knowledge, industry models, and analytical approaches, courses as well-suited to online learning. These types of skills can be adapted to an online setting without a significant loss of rigor or fidelity (Means, Bakia, & Murphy, 2014).

Additionally, MOOC-based online and blended degree programs may work best in areas where students are already price and time sensitive. Blended students reported that the lower price and shorter time frame were factors in their decision to apply to the blended program. For degree program directors in competitive fields, our findings suggest that MOOC-based blended options can attract students who may not have applied to a traditional residential graduate program. Our research complements findings from Goodman et al. (2016), who found causal evidence that students who just missed the cut score for admissions into a fully MOOC-based master's degree in computer science at Georgia Tech did not enter any other degree program.

Our study of a single program provides one perspective of how MOOCs might settle into the landscape of higher education. We demonstrate how one university expanded their reach in the supply chain management field by creating a MOOC-based credential and blended master's degree alongside a traditional residential master's degree. The program attracted some new types of students who would not have otherwise applied to the traditional residential program, but there was little evidence that this new pathway was a promising new on-ramp for those with limited access to post-secondary education. Technological affordances of MOOCs will likely

neither transform higher education nor solve its most stubborn challenges, however, these findings suggest that there may be particular niches where MOOCs provide a valuable service to learners.

Notes

¹ As authors, we had no role in the development or facilitation of the program. Our work was funded by the MIT Office of Digital Learning in order to provide guidance to the MIT faculty on the efficacy of this program and to inform the field more broadly.

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Table 1
Student Demographics by Completion Level and Blended and Residential cohorts

	Mean Age (SD)	% Male	% North American	% OECD Country	% Master's Degree	N
Non-verified students Did not pay the verification fee	32.4 (9.1)	76%	29%	49%	35%	74,597
Verified, non-completers Paid verification fee but did not complete any courses	34.7 (9.1)	75%	53%	70%	35%	4,364
Verified, partial completers Paid verification fee and completed at least one course	33.9 (8.5)	78%	38%	64%	44%	3,405
MicroMasters Earned the MicroMasters credential, did not enroll in the blended program	35.1 (7.9)	88%	45%	68%	51%	582
Blended Earned MicroMasters and enrolled in the one-semester blended program at MIT	32.0 (5.5)	72%	32%	45%	57%	40
Residential Enrolled in the full-year residential program at MIT	28.9 (3.2)	60%	40%	45%	19%	42

Note. Categories are exclusive and represent students' level of completion as of May 2017 when the first MicroMasters assessment occurred. We excluded students who participated in one of the online courses after May 2017.

Table 2
Average Use of Learning Strategies Within Each Course by Completion Level

	Hours in Course	Number of Forum Posts	Number of Videos Revisited	Number of Correct Problems Revisited	N
Verified, non-completers (Reference)	8.21	0.80	2.19	1.19	4,364
Verified, partial completers	18.72***	2.11***	6.52***	1.33***	3,405
MicroMasters	28.87***	3.53****	15.23***	1.77***	582
Blended	35.20***	26.02****	17.20***	1.76***	40

Note. Categories are exclusive and represent students' level of completion as of May 2017. We excluded students who participated in one of the online courses after May 2017. We defined a "revisit" as returning to a video or problem on a different day to differentiate intentional revisiting content from other types of behaviors.

FIGURE 1. *Funnel of participation within the MIT supply chain MicroMasters program*

Note. Participation levels as of May 2017 when applications for blended programs were due. We excluded any participants who completed additional courses after the May 2017 deadline.

FIGURE 2: *On-campus learning experiences by cohort*

Note. Observed percentages reported using stacked bar graphs with top two categories highlighted.

FIGURE 3: *Difference in January and spring semester GPA scores by cohort*

Note. Means reported are observed mean GPA by cohort in January and spring semester courses with 95% confidence intervals. For non-SCM students we only report course performance in courses with at least one SCM student.

Supplementary Online Materials: Full Methods Description

This section presents additional details about the methods used in this study of the MIT Supply Chain Management MicroMasters and associated blended master's degree program. We describe the quantitative and qualitative data sources used in this study and our approaches to analyzing the data for this study.

Data Sources

Log data

We analyzed log data from edX from all students ($N = 82,988$) who participated in one of the five MOOC courses in the program (with 8 total course runs) from April 2015 to May 2017. We assessed the edX data using tables generated in Google BigQuery using the `edx2bigquery` open-source Python package (Lopez, Seaton, Ang, Tingley, & Chuang, 2017). For our analysis of self-regulated learning in the MicroMasters, we examined four research-based indicators of self-regulated learning activity: the total time spent in the course, the number of times users posted in the community forums, the number of times users revisited previously watched videos, and the number of times users revisited previously completed assessments.

Demographic Data

All students are asked to fill out a brief demographic survey when signing up for courses on edX.org. The survey included questions about their age, gender, and level of education. Additionally, the edX server records the modal IP address of each student when they are taking the course which allows for identification of user's country.

Entrance Surveys.

Students were administered entrance surveys before starting each of the courses in the MicroMasters sequence ($N = 33,279$). The survey questionnaire asked participants about their background, motivation for participation, and frequency of setting learning goals. We matched at least one entrance survey for 29% of non-verified participants, 65% of verified students who did not complete any courses, 81% of students who certified for at least one course but did not complete the sequence, 96% of MicroMasters completers, and 92% of blended students.

In-Person Interviews.

We conducted semi-structured interviews at the beginning of the January term. Invitations were sent to all students in both the blended and comparable full-year residential cohort. We interviewed $N = 33$ blended students (83% response rate) and $N=18$ residential students (43% response rate). We also conducted follow-up interviews at the end of the semester with a random sample of the blended students that we interviewed during the first round of interviews ($N = 9$, 60% response rate)

End-of-Semester Surveys.

We administered an end-of-semester survey to student in both the blended (N=34; 85% response rate) and residential cohorts (N=34; 81% response rate). The survey asked students about their academic experiences in their residential courses, interactions with faculty and other students, and their sense of belonging to the institution. Survey items were adapted from items from existing surveys on student experiences in higher education (Haussmann, Ye, Schofield, Woods, 2009).

Academic Grades

We received de-identified course grades for students in both the blended and residential cohorts from the university's office of institutional research. These grades included both classes offered within the degree program and electives students took outside of the program at MIT. Additionally, we obtained the grade distributions of students not enrolled in the supply chain management program for any classes where there was at least one blended or residential student in the class. We standardized students course grades so they were a on a 0-4 point grading scale (e.g., 3.7 = A-, 4.0 = A).

Data Analysis

Mixed-Methods Design

This study used iterative integrated mixed methods design. In integrated mixed method designs, the "mixing" of the data occurs throughout the inquiry process; from data collection through the interpretation phase (Teddle & Tashakkori, 2006). Iterative integrated designs allow this process to occur over several stages, allowing what Caracelli and Greene (1997) describe as the "progressive reconfiguration of substantive findings and interpretations in a pattern of increasing insight and sophistication" (p.23). Using this approach allows exploration into the interplay between the qualitative and quantitative data sources, and allowed us to modify our data collection and analysis in response to new information (Caracelli & Greene, 1997) .

Interview Coding and Analysis

We approached qualitative coding of the data using a grounded theory approach; where there are no pre-existing assumptions about the structure or themes in the data (Glaser & Strauss, 1967). We chose this approach because MOOC-based online and blended pathways are relatively new and we wanted to have the flexibility to pursue new ideas and concepts that emerge within the data without being constrained by pre-existing models that might not fit the data (Heath & Cowley, 2004).

We began the process of coding the interviews by open coding a sample of interviews (N = 8) using a constant comparative approach (Boeije, 2002; Glaser & Strauss, 1967). Each interview was coded by independently by three raters (one author and two undergraduate research assistants) to identify emergent themes in the data. We then collapsed these codes into a set of 11 axial codes that we consistently identified across different interviewees (see Table 1).

Once we decided on the 11 axial codes, we conducted a norming exercise to ensure that all coders had a consistent understanding of how to apply the codes. Each coder

independently coded 41 excerpts from two interviews. We then calculated the pooled kappa which is a version of Cohen's kappa that can be applied in situations where there are multiple codes that could potentially be applied to the same line of text (De Vries, Elliot, Kanouse, & Teleki, 2008). We calculated a pooled kappa of 0.70 on the excerpts from the norming exercise.

We then coded the remaining interviews that were not included in the norming exercise. Of the remaining interviews, 43% (N = 18) were coded by at least two independent raters. The overall pooled kappa from all of the interviews was and no combination of raters had a pooled kappa lower than 0.67. In Table A1 we present the distribution of codes by cohort.

Table A1
Distribution of Codes by Blended and Residential Cohort

Code	Code Description	Blended	Residential
Biographic Info	Information about participants background, where they grew up, their class upbringing, undergraduate.	11.1%	11.8%
Previous employer	Experience with previous employers	11.0%	7.3%
Employer support for learning	Previous employers views on outside learning and supporting attendance in the program	4.7%	1.0%
Reasons for coming to the program	Reasons for signing up for online courses or for applying to the residential program	14.5%	14.4%
Online learning	Experiences with online learning, strategies that people used when learning online, and advantages of online learning	22.4%	9.0%
Learning preferences	Subject/content that the learner is interested in and ways that the learner prefers to learn	7.4%	5.9%
Interaction with other students online	Interactions with other students in the online community for example participation in forums, WhatsApp groups, and meeting other students from online in person	7.8%	1.1%
Connections between content and job functions	Descriptions of how the content the learn connected to their job and how they applied their learning while at their job	5.6%	2.6%
In-person learning experiences	Experience with in-person learning such as the benefits of in-person compared to online learning and aspects of learning in the residential program.	7.7%	17.8%
Interaction with other students in the residential program	Interactions with other students during the fall semester (residential), interactions between blended students and residential students.	8.8%	22.4%
Plans for future jobs	Plans for finding a new job, experience with recruitment, challenges with finding a new job	7.6%	15.9%

Note. Codes add up to more than 100% because multiple codes could be applied to the same line of text

Quantitative Methods

In this section, we describe the data preparation and analysis of each figure and table in the paper.

Figure 1. Funnel of Participation within the Supply Chain Micromasters

We defined the analytic sample as any participant who participated in the SCM MicroMasters courses prior to the May 2017 deadline for admission into the blended program. We defined participation as having clicked at least once into the course: people who registered but did not interact with the course were excluded from the analysis. In order to account for participants who were part-way through the program at that time, we excluded any participants who participated in any additional courses between May 2017 and October 2018 when the analysis was conducted. We also excluded participants who did not earn a MicroMasters prior to the May 2017 deadline but later earned a MicroMasters during additional administrations of the proctored assessment.

Within the analytic sample, we defined five categories of users: Non-verified participants; Verified, non-completers; Verified, partial completers; MicroMasters students, and Blended students.

Non-verified participants were participants who did not pay the verification fee for any course and were thus ineligible to earn a MicroMasters. Note that prior to December 2015, edX offered free “honors” certificates to people who agreed to abide by an honor code. Thus, students could earn a certificate but it would not have accounted toward the MicroMasters.

Verified, non-completers were participants who paid the verification fee for at least one course but did not complete any courses. By paying a several hundred dollar verification fee, these students expressed a strong interest in engaging in the courses but did not finish.

Verified, partial completers were participants who paid the verification fee and completed at least one course but did not complete the entire five-sequence and pass the proctored assessment.

MicroMasters participants passed the first proctored MicroMasters assessment and earned the credential, but did not enroll in the blended program.

Blended participants earned the MicroMasters credentials and then applied, were admitted, and enrolled into the blended master’s program at MIT.

In order to show the “funnel” of participation, we presented each category with all subsequent categories “nested” in the count. For example, when we reported that 82,988 participated in the courses this included the 8,391 who verified for the course. In subsequent tables, we presented an exclusive version of each category in order to make comparisons across cohorts.

Table 1. Student Demographics by Completion Level and Blended and Residential cohorts

For the table, we use the same five participant categories (non-verified participants, verified non-completers, verified partial completers, MicroMasters, and Blended), but we define them as five exclusive, non-nested categories. From these, we calculated descriptive statistics for age in 2017, gender, and highest degree earned. We also used the reported country of origin to determine whether the participant was from North America and from a country in the OECD (see <http://www.oecd.org/about/membersandpartners/list-oecd-member-countries.htm> for a list of countries). In cases where students took courses in multiple countries, we used the modal country across all the courses in which the student participated.

Missing data, though present, was not a major issue with demographic data. Country identification was missing from 8.6% of participants, education level was missing from 10.5% of participants, gender from 8.5% of participants, and age from 10.0% participants. Because only a small portion of data was missing from each indicator we did not impute missing data for the demographic data.

Table 2. Average Use of Learning Strategies Within Each Course by Completion Level

We conducted a review of the self-regulated literature for MOOCs (Kizilcec, Pérez-Sanagustín, & Maldonado, 2017; Littlejohn, Hood, Milligan, & Mustain, 2016) to decide on indicators to include the analysis. We then calculated for each person and course the following indicators: hours spent in course, the number of times posted on the forums, the number of videos revisited, and the number of correctly answered problems revisited.

Hours Spent in Course. We used an estimate of time spent in the platform developed by researchers at HarvardX and MITx. The estimate calculates the total time between clicks in the course and assumes that any period longer than 5 minutes the user is not actively engaged in the platform (see <https://github.com/mitodl/edx2bigquery> for documentation)

Number of Times Posted on the Forums. We calculated the total number of times the student posted on the community forum using the associated person-course table from the BigQuery account.

Number of Videos Revisited. We calculated the number of times participants reviewed a previously completely watched video. To account for students accidentally re-clicking on a video, we defined a review as having watched the video on a different day than when they previously watched the video.

Number of Correctly Answered Problems Revisited. For each problem in a course, we calculated the number of times a student attempted a problem after they had already answered it correctly. Similar to the video indicator, we excluded any attempts on the same day which may have been caused by students accidentally re-clicking on assessment item.

All of these indicators were calculated at the individual person and course-level and then aggregated by the level of completion of the online program. We then computed inferential statistics using the non-parametric Wilcoxon-Mann-Whitney tests because of the heavily skewed distribution of the data. A Wilcoxon-Mann-Whitney test is preferable in cases with heavily skewed distributions because it has greater statistical power and is a more efficient estimator (Fay & Proschan, 2010).

Figure 2. On-Campus Learning Experience by Cohort

We calculated the distribution of responses by cohort to a set of survey question asked on the end-of-semester survey. Table A2 presents the full text of the survey questions and the average scores, on a six-point scale, for each cohort. Only the academic preparation indicator was statistically significantly different between the two cohorts ($p < 0.01$). However, this may be due to the fact that blended students were responding to the question based on their preparation in the online courses while the residential students were responding based on their preparation prior to starting the residential program. We chose to report the findings using stacked bar graphs with the top-two categories highlighted in order to emphasize the high overall level of agreement with the survey-items and the relatively minor differences between the blended and residential cohorts.

Table A2
Differences in Average Response by Blended or Residential Cohort

	Blended	Residential	Difference	P-value
I felt academically prepared for the courses I took in the Supply Chain Management Program.	5.72	5.22	0.50	0.0013
I learned a lot from working on teams with other students in the Supply Chain Management program.	4.97	4.78	0.19	0.5178
My relationships with other students have had a positive influence on my intellectual growth while at MIT.	5.22	5.56	-0.34	0.1051
I feel a sense of belonging to MIT.	5.31	5.22	0.09	0.6954
I see myself as a part of the larger MIT community.	5.25	4.97	0.28	0.2531
I am confident I made the right decision to attend MIT.	5.56	5.62	-0.06	0.7177

Figure 3. Differences in January and Spring Semester GPA Scores by Cohort

In this study, we compared the aggregate January term and spring semester grades for three groups of student: blended, residential, and students outside of the SCM program. We estimated student differences course grades using three different model specifications: 1) Comparing the observed mean GPA for each group with no statistical adjustments; 2) Estimating a regression model with fixed-effects for each course to control for course selection; and 3) a cross-classified random effects model that accounts for both between-course and between-person variation in grades. For the third model, we were only able to estimate differences between the blended and residential students because we did not have individual-level identifiers for non-SCM students.

In Table A3 we present the estimated differences in average GPA with each of the three modeling approaches. With all three modeling approaches, the blended students had the highest estimated GPA and the differences were statistically significant. Because all three modeling approaches produced the same result, we chose to present the differences in observed GPA because that approach was the most parsimonious and intuitive.

Table A3: Differences in Estimated GPA by Modeling Approach

Group	Model 1: Observed mean GPA differences	Model 2: Course fixed-effects model	Model 3: Cross-classified random effects model
Blended	--	--	--
Residential	-0.107 (0.033)**	-0.110 (0.034)**	-0.087 (0.034)**
Non-SCM	-0.246 (0.024)***	-0.154 (0.042)***	--

Note. Differences are estimated differences from blended cohort. Standard errors are in parenthesis. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

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