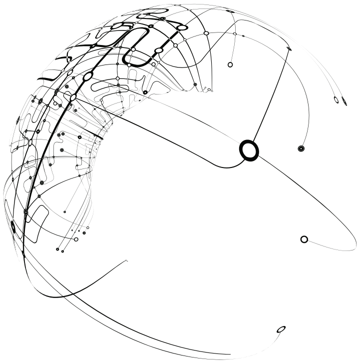

Abstract

"Circuits and Electronics" (6.002x), which began in March 2012, was the first MOOC developed by edX, the consortium led by MIT and Harvard. Over 155,000 students initially registered for 6.002x, which was composed of video lectures, interactive problems, online laboratories, and a discussion forum. As the course ended in June 2012, researchers began to analyze the rich sources of data it generated. This article describes both the first stage of this research, which examined the students' use of resources by time spent on each, and a second stage that is producing an in-depth picture of who the 6.002x students were, how their own background and capabilities related to their achievement and persistence, and how their interactions with 6.002x's curricular and pedagogical components contributed to their level of success in the course.

AUTHORS

Lori Breslow, Ph.D.
Massachusetts Institute of Technology

David E. Pritchard, Ph.D.
Massachusetts Institute of Technology

Jennifer DeBoer, Ph.D.
Massachusetts Institute of Technology

Glenda S. Stump, Ph.D.
Massachusetts Institute of Technology

Andrew D. Ho, Ph.D.
Harvard University

Daniel T. Seaton, Ph.D.
Massachusetts Institute of Technology

CORRESPONDENCE

Email
lrb@mit.edu

Parts of this work have been submitted for presentation/publication at the American Educational Research Association (AERA) conference, the Educational Data Mining (EDM) conference, the MIT Learning International Networks Consortium conference (LINC), and *Communications, Association for Computer Machinery*. We are grateful for assistance with the research and presentation of the data in this paper from Dr. Y. Bergner.

Studying Learning in the Worldwide Classroom Research into edX's First MOOC

From the launch of edX, the joint venture between MIT and Harvard to create and disseminate massive online open courses (MOOCs), the leaders of both institutions have emphasized that research into learning will be one of the initiative's core missions. As numerous articles in both the academic and popular press have pointed out, the ability of MOOCs to generate a tremendous amount of data opens up considerable opportunities for educational research. edX and Coursera, which together claim almost four and a half million enrollees, have developed platforms that track students' every click as they use instructional resources, complete assessments, and engage in social interactions. These data have the potential to help researchers identify, at a finer resolution than ever before, what contributes to students' learning and what hampers their success.

The challenge for the research and assessment communities is to determine which questions should be asked and in what priority. How can we set ourselves on a path that will produce useful short-term results while providing a foundation upon which to build? What is economically feasible? What is politically possible? How can research into MOOCs contribute to an understanding of on-campus learning? What do stakeholders—faculty, developers, government agencies, foundations, and, most importantly, students—need in order to realize the potential of digital learning, generally, and massive open online courses, specifically?

This paper describes an initial study of the data generated by MIT's first MOOC, "Circuits and Electronics" (6.002x)[1] by a team of multidisciplinary researchers from MIT and Harvard. These data include the IP addresses of all enrolled students; clickstream data that recorded each of the 230 million interactions the students had with the platform (Seaton, Bergner, Chuang, Mitros, & Pritchard, 2013); scores on homework assignments, labs, and exams; student and teaching staff posts on a discussion forum; and the results of a survey sent to the 6.002x students at the end of the course. We are trying to understand who the students were in 6.002x, how they utilized course resources, what contributed to their persistence, and what advanced or hindered their achievement. In other words, we are trying to make headway in answering the question Davidson (2012) has posited is central to on-line learning: "What modes of learning work in what situations and for whom?"

If educational researchers studying conventional brick and mortar classrooms struggle to operationalize variables like attrition and achievement, it is doubly difficult to do so for MOOCs. Participation and performance do not follow the rules by which universities have traditionally organized the teaching enterprise: MOOCs allow free and easy registration, do not require formal withdrawals, and include a large number of students who may not have any interest in completing assignments and assessments.

Our first challenge has been choosing, or in some cases adapting, the methodological approaches that can be used to analyze the data. If educational researchers studying conventional brick and mortar classrooms struggle to operationalize variables like attrition and achievement, it is doubly difficult to do so for MOOCs. Participation and performance do not follow the rules by which universities have traditionally organized the teaching enterprise: MOOCs allow free and easy registration, do not require formal withdrawals, and include a large number of students who may not have any interest in completing assignments and assessments. We are experimenting with new ways to study educational experiences in MOOCs, as naïve applications of conventional methods to the unconventional data sets they generate are likely to lead, at best, to useless results, and, at worst, to nonsensical ones.

As of this writing, our analyses have yielded a clearer picture of the first two questions we are exploring—the characteristics of the students and their use of course resources—and we report on these findings below. However, we are still in the process of developing the predictive models that will help us understand how both student background and interaction with course components contributed to or hampered the students' ability to persist in the course and, for some, to earn a certificate. Therefore, these analyses are not included in this paper.

For readers unfamiliar with MOOCs, in general, and with the MITx course, specifically, we begin with a short description of 6.002x. We then describe a first study that was carried out in summer through fall 2012, and the second stage of research that is currently underway. Finally, we consider some of the implications of our findings and suggest further directions our research, as well as other studies of MOOCs, may take.

"Circuits and Electronics" (6.002x)

"Circuits and Electronics" (6.002) is a required undergraduate course for majors in the Department of Electric Engineering and Computer Science. The first iteration of the edX version of 6.002 began in March 2012 and ran for 14 weeks through the beginning of June. It was offered again in fall 2012 and spring 2013.[2] The lead instructor for 6.002x was a MIT faculty member who has taught the on-campus version of the course over a number of years. He was joined by three other instructors, two MIT professors and edX's chief scientist, who were responsible for creating the homework assignments, labs, and tutorials, as well as five teaching assistants and three lab assistants.

Each week, a set of videos, called lecture sequences, was released. These videos, narrated by the lead instructor, average less than 10 minutes and are composed of illustrations, text, and equations drawn on a tablet (i.e., "Khan Academy" style). Interspersed among the videos are online exercises that give students an opportunity to put into practice the concepts covered in the videos. The course also includes tutorials similar to the small-group recitations that often accompany MIT lecture courses; a textbook accessible electronically; a discussion forum where students can have questions answered by other students or the teaching assistants; and a Wiki to post additional resources.

[1] 6.002x was originally introduced on MITx, the organization MIT established before it was joined by Harvard to create edX. "MITx" now identifies the specific courses developed at MIT that are distributed on the edX platform.

[2] Interested readers can access the spring 2013 version of the course at https://www.edx.org/courses/MITx/6.002x/2013_Spring/about

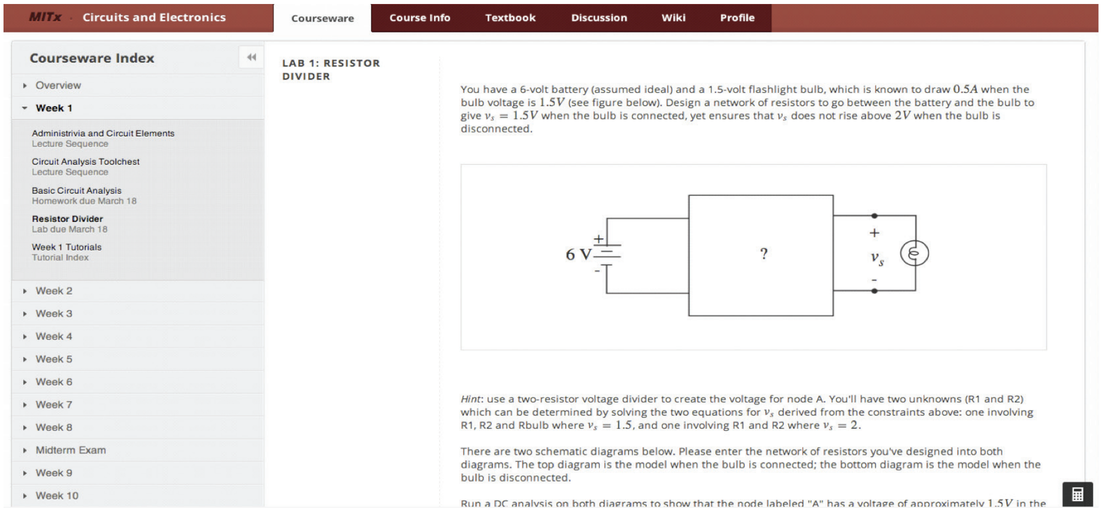

Figure 1. *Screen shot from "Circuits and Electronics" (6.002x) with navigation bar on left.*

As specified in the 6.002x syllabus, grades were based on twelve homework assignments (15%), twelve laboratory assignments (15%), a midterm (30%), and a final exam (40%). Two homework assignments and two labs could be dropped without penalty. Students needed to accrue 60 points in order to receive a certificate of completion. They received an "A" if they earned 87 points or more, a "B" for 86 through 70 points, and a "C" for 69 through 60 points. As has been widely reported, almost 155,000 people enrolled in 6.002x and just over 7,100 passed the course and earned a certificate (Hardesty, 2012).

It should be stressed that over 90% of the activity on the discussion forum resulted from students who simply viewed preexisting discussion threads, without posting questions, answers, or comments.

Within a short period of time, studies related to 6.002x were begun at MIT. During spring 2012, researchers from MIT's Research in Learning, Assessing, and Tutoring Effectively (RELATE) group began mining the data from the course to identify trends in the use of the various resources. In June 2012, MIT received an overture from the National Science Foundation to continue research on the 6.002x data set. A joint proposal was submitted by researchers from MIT's Teaching and Learning Laboratory and the Harvard Graduate School of Education to examine student demographics, online communities, and achievement and persistence among 6.002x students. As noted above, this article reports on that research to date.

First Study Explores Resource Usage

The first analysis of the 6.002x data set examined how the certificate earners allocated their time and attention over the course among the various course components. This research also explored how the behavior of certificate earners differed when solving homework versus exam problems. Each topic is addressed via the graphs below in Figure 2.

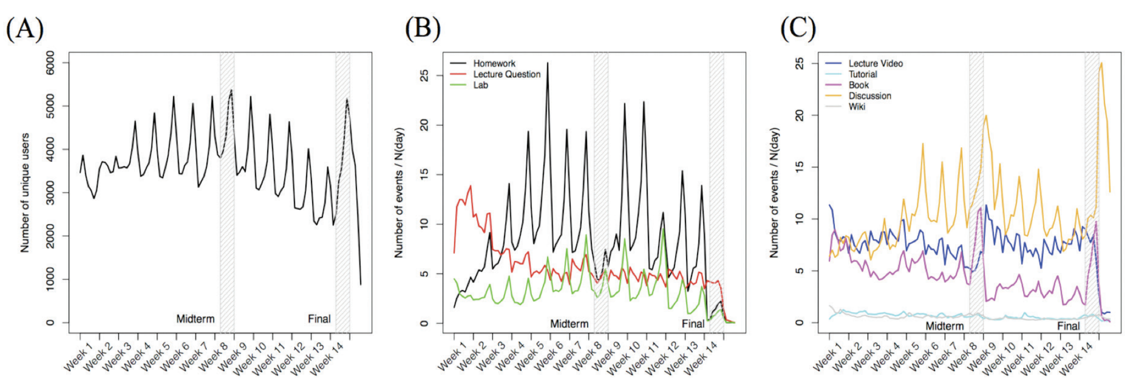

Figure 2. *Course components that were accessed in 6.002x. From left to right (A) number of unique certificate earners active per day; (B) the average number of accesses each day for assessment-based; and (C) learning-based course components.*

Plot A highlights the weekly periodicity; peaks on weekends presumably reflect both the days when spare time is available and the deadline for homework submission. In plots B and C activity is shown in hits per user each day. The three instructional resources—textbook, video lectures, and lecture questions—display little end-of-week peaking, whereas for–credit assessments (homework and labs) show marked peaks suggesting these activities were done just ahead of the deadline. The discussion forum shows similar periodicity because it is accessed while doing the homework problems (for more on the use of the discussion forum, please see below). The drop in e-text activity after the first exam is typical of textbook use that has been observed in blended on-campus courses where the textbook was a supplementary resource (that is, not part of the sequence of activities presented to students by the interface).

Students came from 194 countries, virtually all in the world. The top five countries were the United States (26,333), India (13,044), the United Kingdom (8,430), Colombia (5,900), and Spain (3,684). Although it was speculated that many Chinese students would enroll, in fact, we counted only 622 Chinese registrants.

Time represents the principal cost function for students, and it is therefore important to study how students allocated their time throughout the course. Clearly, the most time was spent on lecture videos (see Figure 3). However, the assigned work (i.e., homework and labs) took more time in toto. Use of the discussion forum was very popular considering that posting on the forum was neither for credit nor part of the main "course sequence" of prescribed activities. It should be stressed that over 90% of the activity on the discussion forum resulted from students who simply viewed preexisting discussion threads, without posting questions, answers, or comments.

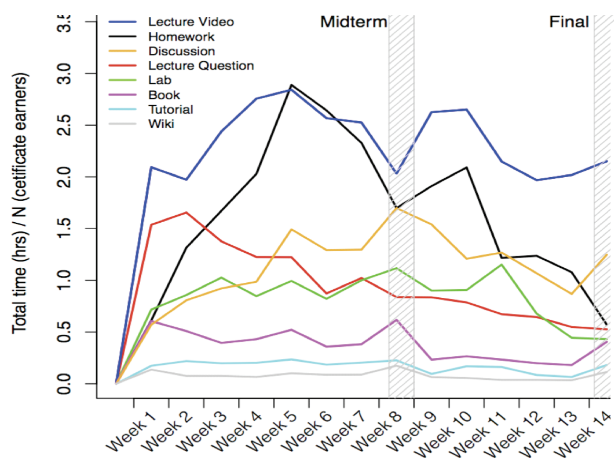

Figure 3. *Time on task. Certificate earners average time spent in hours per week on each course component. Midterm and final exam weeks are shaded.*

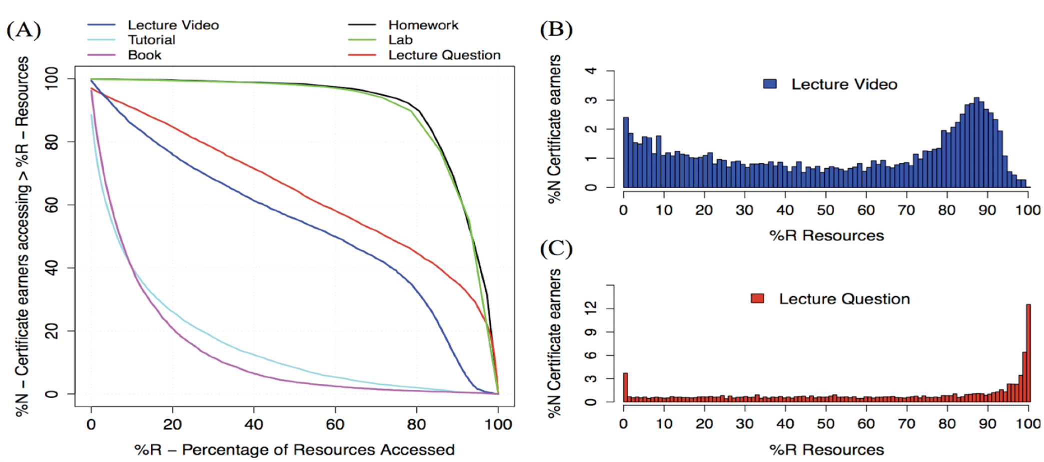

Figure 4. *Fractional use of resources: (A) the percentage of certificate earners that accessed greater than %R of that type of course resources; (B) the bimodal distribution for percentage of videos accessed; (C) distribution for the lecture questions.*

Discussions were the most frequently used resource while doing homework problems and lecture videos consumed the most time. During exams, old homework problems were most often referred to, and most time was spent with the book, which is otherwise largely neglected. This undoubtedly reflects the relevance of old homework to exams, and the ease of referencing the book for finding particular help.

Another interesting feature revealed by these data is student strategy in solving problems. By strategy, we mean which resources were most frequently consulted by the students while doing problems, and which ones were viewed for the longest time? Student strategy differs very markedly when solving homework problems versus when solving exam problems. (Note: the exams were "open course" so all resources were available to the students while they took the exams.) This finding is illustrated in Figure 5.

We know, too, from an open-ended profile edX posted at the start of the course, 67% of registrants spoke English, and 16%, the next largest group, spoke Spanish.

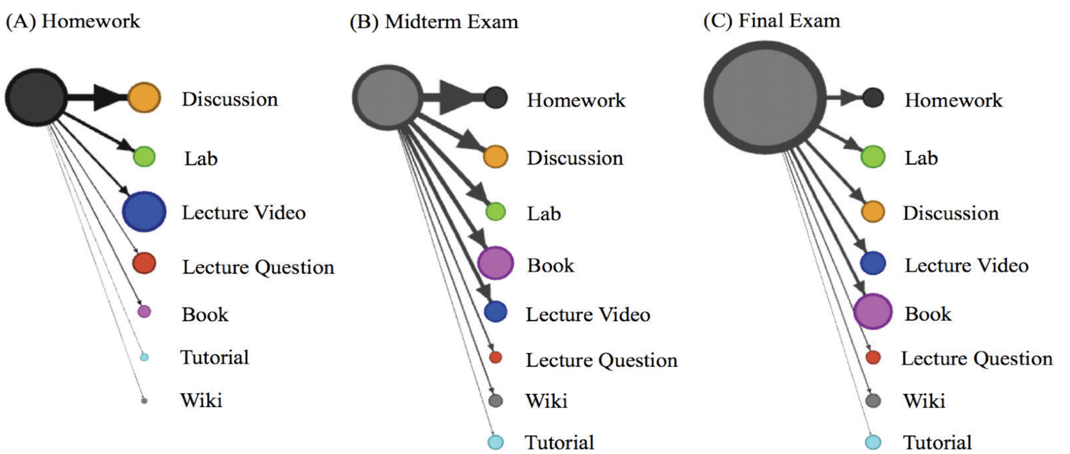

Figure 5. *Which resources are used while problem solving? Activity (hits), registered by thicker arrows, is highest for resources listed at the top. Node size represents the total time spent on that course component.*

Second Stage of Research Examines Demographics, Achievement, and Persistence

Building from the work described above, a second phase of research began in fall 2012. This study sought to answer the broad question, "Who were the students who enrolled in 6.002x, and what factors related to their level of success in the course?" This research complements the analysis of resource usage by attempting to construct a detailed picture of the 6.002x students, using multiple sampling frames: all registrants, all students who clicked on the course website, students who demonstrated different levels of engagement of the course, and certificate earners. Next, we hope to be able to identify relationships between the characteristics and capabilities of the students themselves and their success. Finally, we want to understand how the curricular and pedagogical components of 6.002x contributed to the students' ability to master the material.

Diversity in Location and Demographics

We began this research by investigating the locations from which students accessed the 6.002x site because the student's IP address was recorded each time he or she interacted with the website. We used a geolocation database to identify login locations. For nearly all IP addresses we could identify, we could determine the country from which a student logged in, and for many addresses, we could identify the city.[3] Students came from 194 countries, virtually all in the world. The top five countries were the United States (26,333), India (13,044), the United Kingdom (8,430), Colombia (5,900), and Spain (3,684). Although it was

[3] There is some error associated with this procedure, as students could log in from proxy servers or otherwise mask their IP address; however, we found less than 5% of the students were likely to be misidentified due to altered IP addresses.

speculated that many Chinese students would enroll, in fact, we counted only 622 Chinese registrants. Interestingly, we also saw a small but notable number of students who logged in from multiple countries or multiple cities within the same country. Figure 6 illustrates the widespread distribution of 6.002x students around the world.

Figure 6. *Locations of 6.002x students throughout the world.*

We know, too, from an open-ended profile edX posted at the start of the course, 67% of registrants spoke English, and 16% , the next largest group, spoke Spanish. Students who were not native English speakers formed Facebook groups to help each other with the course, and we noted a small number of posts on the discussion forum in languages other than English.

We assume some students were continuing to follow the course even if they were not doing the assignments or taking the exams.

An end-of-the-course survey was developed to gather more data about the students and their background. Because edX wanted to test the willingness of students to answer survey questions, the number of questions sent to individual students, as well as the specific questions they were asked, were distributed randomly through a link on the student's profile page. Of the 7,161 students who completed the survey, the largest group by far, 6,381 respondents, were certificate earners. However, over 800 of the respondents had not earned a certificate, so we assume some students were continuing to follow the course even if they were not doing the assignments or taking the exams. The survey questions, which were grounded in research in large-scale studies in international education, included not only demographics such as age and gender, but asked students, for example, about their home environment and their educational and professional background. This is in line with educational research (Coleman et al., 1966; Gamoran & Long, 2008) that indicates these latter variables serve as important controls in predictions of educational outcomes.

Some of the findings were not particularly surprising. For example, of the over 1,100 students who were asked about their age on the particular survey they received, most reported they were in their 20s and 30s, although the entire population of 6.002x students who responded to that question ranged from teenagers to people in their seventies. Figure 7 shows the age distribution of 6.002x students.

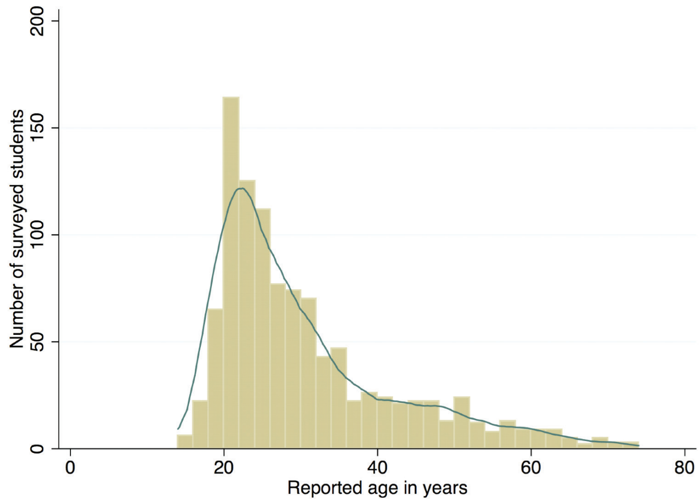

Figure 7. *Age distribution*

As might also be predicted, 88% of those who reported their gender were male. Of the survey responders who answered a question about highest degree attained, 37% had a bachelor's degree, 28% had a master's or professional degree, and 27% were high school graduates. Approximately three-quarters of those who answered the question about their background in math reported they had studied vector calculus or differential equations. In fact, the 6.002x syllabus advised students that the course required some knowledge of differential equations, along with a background in electricity and magnetism (at the level of an Advanced Placement course) and basic calculus and linear algebra.

Given that the topic of circuits and electronics has professional applications, we were not surprised to learn that over half the survey respondents reported the primary reason they enrolled in 6.002x was for the knowledge and skills they would gain. Although, interestingly, only 8.8% stated they registered for the course for "employment or job advancement opportunities." Over a quarter of the students took the course for the "personal challenge." We saw this latter motivation reflected in the discussion forum, with participants along the entire spectrum from high school students to retired electrical engineers explaining they were taking 6.002x because they wanted to see if they could "make it" through a MIT course. Figure 8 details the primary reason for enrollment for students who answered this question on the survey. There were no correlations between motivation for enrollment and success in the course. Whether students were taking 6.002x to advance their knowledge or because they wanted the challenge (we realize, of course, the two could be interrelated), it did not seem to affect their performance in the class. We are curious about how the motivation for enrollment in a course like 6.002x compares with the humanities MOOCs that have subsequently been developed.

There were no correlations between motivation for enrollment and success in the course. Whether students were taking 6.002x to advance their knowledge or because they wanted the challenge (we realize, of course, the two could be interrelated), it did not seem to affect their performance in the class.

What Contributed to Student "Success"? Predictive Modeling as the Next Step in the Analysis

The information we have collected on the students who took 6.002x offers insight into where they came from and the languages they spoke, and, for some, their educational background, the reasons they enrolled in the course, etc. Our next step is to carry out more sophisticated predictive analyses, first examining what factors individual to the students might be correlated with their success and then analyzing the relationships between the students' use of course components (e.g., hours spent doing homework, reading the textbook, or watching the lecture videos) and success. The first stage in this work is to define more precisely what we mean by "success" in a MOOC.

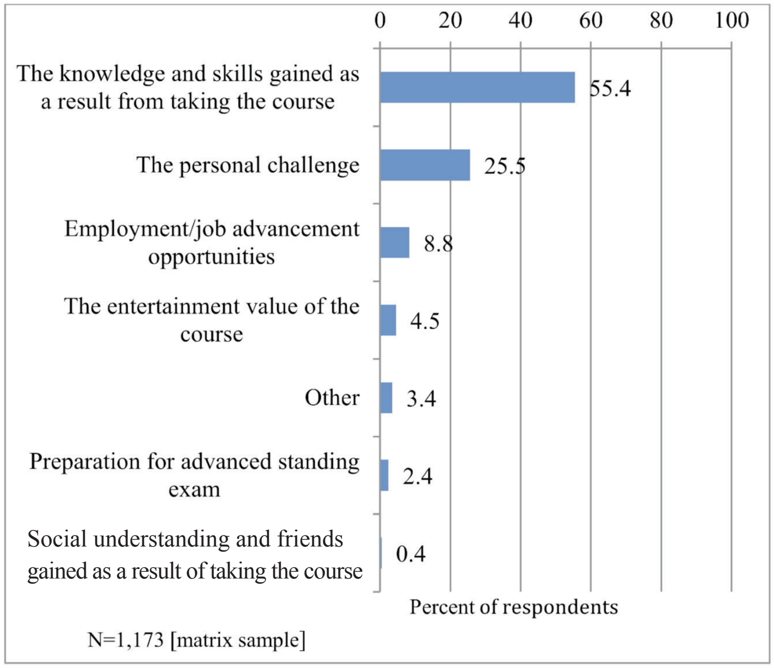

Figure 8. *Reasons for enrolling in 6.002x as reported on end-of-course survey.*

Success as Achievement

In many ways, 6.002x mirrors its on-campus counterpart: it is built from lectures, albeit shorter ones than in a traditional college course, with questions embedded between lectures so students can work with the concepts just explained in the video. 6.002x also included tutorials and laboratories. Similarly, the edX students were assessed in the same way as their on-campus counterparts—through the scores they earn on homework assignments, labs, and a midterm and final. Thus, we argue, that "success" in 6.002x can be defined as it is in the traditional college classroom, namely, by the grades students earned. We have labeled this measure of success as "achievement," and in some (but not all—please see below) of our models, "achievement" is defined as "total points in the course, weighting the individual assessments (i.e., homework, lab assignments, midterm, and final) as originally laid out in the syllabus."

Thus, we argue, that "success" in 6.002x can be defined as it is in the traditional college classroom, namely, by the grades students earned.

Using this definition, we found no relationship between age and achievement or between gender and achievement, and we found only a marginal relationship between highest degree earned and achievement. There is a correlation between students' previous course experience in mathematics and achievement, but, again, students were told at the onset of the course that they needed to know basic calculus and linear algebra, as well as have some familiarity with differential equations.

The strongest correlation we found between what we are calling "student background" and achievement was in whether or not the survey respondent "worked offline with anyone on the MITx material." The vast majority of students who answered this question (75.7%) did not. However, if a student did collaborate offline with someone else taking 6.002x, as 17.7% of the respondents reported, or with "someone who teaches or has expertise in this area," as 2.5% did, that interaction seemed to have had a beneficial effect. On average, with all other predictors being equal, a student who worked offline with someone else in the class or someone who had expertise in the subject would have a predicted score almost three points higher than someone working by him or herself. This is a noteworthy finding as it reflects what we know about on-campus instruction: that collaborating with another person, whether novice or expert, strengthens learning.

The next phase of our research is to carry out more sophisticated predictive analyses, exploring, as mentioned above, relationships between the students' use of course components and their achievement. We want to see if certain instructional practices that are known to strengthen learning in the traditional classroom do so in MOOCs. For example, we know that mastery of knowledge and skills is often fostered by the use of "pedagogies of engagement" (e.g., Smith, Sheppard, Johnson, & Johnson, 2005), and we can explore interactive engagement in 6.002x, for instance, by estimating the impact of time spent working on online labs. Similarly, we know that retention and transfer are strengthened by practice at retrieval (e.g., Halpern & Moskel, 2003), and we can study the effect of this instructional practice by looking at the relationship between scores on practice problems and the final exam score in the course. Our goal is to begin to identify the types of curricular materials and pedagogical strategies that optimize learning outcomes for groups of learners who may differ widely in age, level of preparedness, family or work responsibilities, etc.

For some of these analyses, we have experimented with operationalizing "achievement" in two different ways: as scores on homework assignments or performance on the final. One of the features of 6.002x was that students were permitted an unlimited number of attempts at answering homework questions. Should the performance of a student who took, say, three attempts to answer a question be "equal to" the student who answered the question correctly on the first try? This is one of the issues we are grappling with. As an extension of this work, we are looking at longitudinal performance in the class. We are using panel data methods to analyze the relationship between performance on each assignment and the student's subsequent performance on the following assignment. In other words, we are taking advantage of the fine-grain resolution of the clickstream data—a weekly, daily, or even second-by-second account of student behavior and ability—to create a picture of performance over the entire class. We are also partitioning the variance in scores in a nested model, estimating the amount of variance that could be accounted for by differences between individual students and comparing that to the variance that could be explained by differences between groups of students.

On average, with all other predictors being equal, a student who worked offline with someone else in the class or someone who had expertise in the subject would have a predicted score almost three points higher than someone working by him or herself. This is a noteworthy finding as it reflects what we know about on-campus instruction: that collaborating with another person, whether novice or expert, strengthens learning.

Success as Persistence

One of the more troubling aspects of MOOCs to date is their low completion rate, which averages no more than 10%. This was true of 6.002x as well, with less than 5% of the students who signed up at any one time completing the course. Specifically, of the 154,763 students who registered for 6.002x, we know that 23,349 tried the first problem set; 10,547 made it to the mid-term; 9,318 passed the midterm; 8,240 took the final; and 7,157 earned a certificate. In other words, 6.002x was a funnel with students "leaking out" at various points along the way. Figure 9 shows the stop out rate profile for students throughout the fourteen weeks of the course.

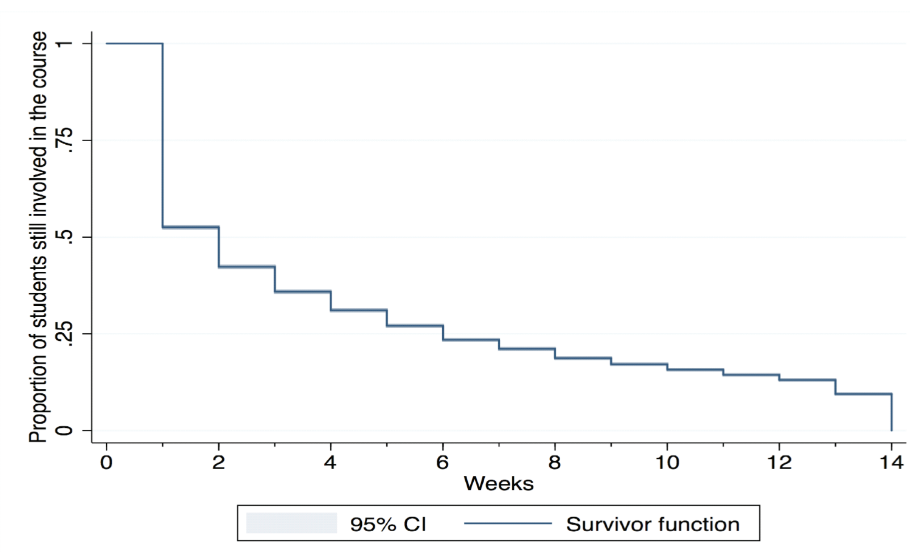

Figure 9. *Stop out rate of students throughout the course.*

We want to understand more about stop out, so we are also operationalizing "success" as "persistence throughout the duration of the course." Here, too, we are working with multiple possible definitions: persistence can be "interaction with *any part of the course* in any subsequent week" or "interaction with a *specific course component* in any subsequent week." Most investigations of students who drop out of traditional learning environments look at their trajectories over the course of a degree program or an entire academic year. Because data were collected more frequently in 6.002x, we can track users as they progressed through the course, and we can see when they chose to stop their participation.

One of the more troubling aspects of MOOCs to date is their low completion rate, which averages no more than 10%. This was true of 6.002x as well, with less than 5% of the students who signed up at any one time completing the course.

We are then estimating a survival function based on student use of resources. While the use of some resources seems to predict an increased likelihood of stopping out of the class in the next week, interactions with other resources seem to predict a decrease in likelihood of stop out. We are extending this model to look at time-varying risk functions—factors that might increase the likelihood of stopping out at the beginning of the course but have the opposite effect at the end of the course. Again, for those who completed the end-of-semester survey, we are able to control for various factors in their background.

Research on the Discussion Forum and On-Campus Use of 6.002x

The third part of this study is an in-depth look at the use of the discussion forum in 6.002x. Participation in interactive learning communities is an important instructional component of MOOCs, and investigations into the students' behavior on discussion forums may elucidate some of the possible causes of student attrition in online courses (Angelino, Williams, & Natvig, 2007; Hart, 2012). Over 12,000 discussion threads were initiated during 6.002x, including almost 100,000 individual posts, providing a rich sample for this analysis. Although the software generating the forum only allowed students to ask a question, answer a question, or make a comment, the content of the posts within those parameters was quite varied. For example, some students utilized the forum to describe how they were struggling with the material, while others offered comments that were tangential to the actual topics of the course.

However, we know that, on average, only 3% of all students participated in the discussion forum. Figure 10 below illustrates the small number of posts the vast majority of students actually made. But we know that certificate earners used the forum at a much higher rate than other students: 27.7% asked a question, 40.6% answered a question, and 36% made a comment. In total, 52% of the certificate earners were active on the forum. We are analyzing the number of comments individual students posted to see if it is predictive of that individual's level of achievement or persistence.

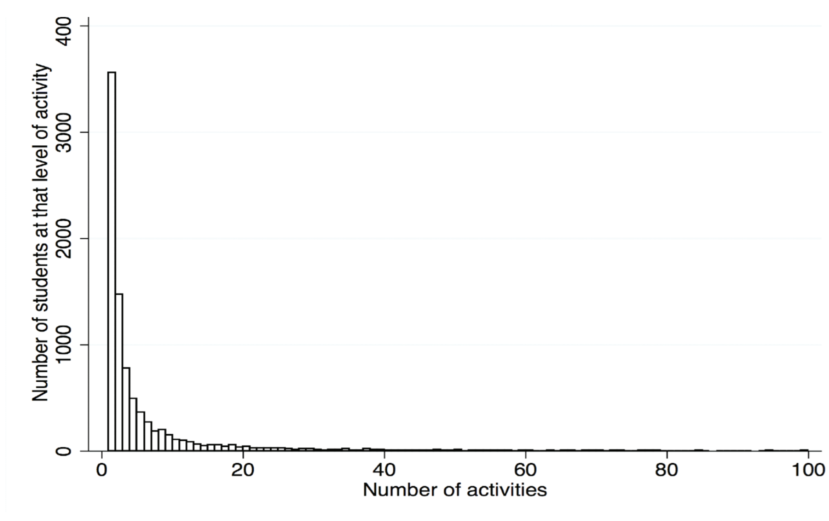

Figure 10. *Distribution of discussion board activity for students with 100 posts or less*

Our initial approach in exploring the discussion forum has been to categorize these interactions very broadly along two dimensions: (a) topic (i.e., course content, course structure or policies, course website or technology, social/affective), and (b) role of the student posting (i.e., help-seeker/ information-seeker or help-giver/information-giver). After we classify the posts using this basic schema, we will be able to describe the general purposes for which the forum was used. We hope to make a contribution to the question that has plagued those who study face-to-face collaboration, and which persists in the MOOC environment—what is the nature of the interactions that create a productive collaboration? Although previous work has shown that informal, unstructured collaboration in face-to-face educational settings is associated with higher student achievement (Stump, Hilpert, Husman, Chung, & Kim, 2011), the relationship between voluntary collaboration and achievement in the larger MOOC environment remains relatively unexplored. We want to understand how "discussion" might have helped 6.002x students to unravel a misconception, understand a difficult topic, or employ an algorithmic procedure. To do this, we are looking more specifically at threads in which students sought and received help on complex homework problems. We are examining the quantity of interactivity between question askers and responders, as well as inferences made by both parties. As yet another means of exploring these data, we are experimenting with social network analysis to see if it yields findings about the nature and longevity of group formation in 6.002x.

The last question we are exploring as part of this study is how on-campus students used 6.002x. We know that approximately 200 MIT students enrolled in 6.002x, and our data show varied levels of their participation throughout the course. We intend to interview those students who were seriously involved with 6.002x to understand their reasons for enrollment and 6.002x's impact, if any, on their studies at MIT. In addition, the Teaching and Learning Laboratory is assessing the use of materials from the edX platform in five courses being taught on campus this semester. The findings from those studies will expand our understanding of the intersection between online and on-campus educational experiences.

The optimists see MOOCs expanding access to previously disenfranchised groups of students, developing new methods of pedagogy for deeper, more sustained learning, and building global communities focused not on the latest fad or celebrity, but on education. Doomsayers predict the end of liberal learning, a generation unable to communicate in face-to-face classrooms, and even the eventual demise of the university.

Directions for Future Research

We hope our investigation of 6.002x will inform both online and on-campus teaching and learning. The appearance of MOOCs in higher education has been swift—so swift, in fact, that it could be called unprecedented. Since their introduction only a scant 18 months ago, there has been no shortage of prophecies about their potential impact. Those predictions have run the gamut from the wildly hopeful to the bleakly dire. The optimists see MOOCs expanding access to previously disenfranchised groups of students, developing new methods of pedagogy for deeper, more sustained learning, and building global communities focused not on the latest fad or celebrity, but on education. Doomsayers predict the end of liberal learning, a generation unable to communicate in face-to-face classrooms, and even the eventual demise of the university. What the two camps agree on—and what history and current events indicate—is that it is unlikely that higher educational will not be affected by MOOCs. Those effects will probably not be as dramatic as promoters or detractors would have us believe, but rather will be more nuanced and complex. A wide range of research will be needed to tease apart that impact, as well as best practices for developing and implementing MOOCs.

The authors of this paper have several areas of research they are particularly keen to explore. For example, we are interested in how the data generated by MOOCs can provide research-based comparisons of instructional strategies. A specific question, for example, is how different representations of complex concepts and phenomena (textual, graphical, mathematical) can best be used to help students master them. In general, we wish to explore how data can be utilized to provide instructors with a clearer picture of what students do or do not understand, and how that information can help them to hone their instructional skills.

Another important research question is, "How can we help students learn more per unit time?" A good way to start is to mine the logs to find what students who improve the most do—which resources they use and in which order. Then experiments will need to be done to see whether incentivizing random students helps them learn faster. The similarity of the structure of 6.002x to traditional courses means that this procedure may well permit us to offer research-based advice to on-campus students taking a traditional course. We believe it will also be vital to better understand student motivation in an online environment. What are students' goals when they enroll in a MOOC? How do those goals relate to the interaction with various modes of instruction or course components? What facilitates or impedes their motivation to learn during a course? How can course content and its delivery support students' self-efficacy for learning? Similarly, how can online environments support students' metacognition and self-regulated learning? Do interventions such as metacognitive prompts and guided reflection improve student achievement or increase retention?

They do not follow the norms and rules that have governed university courses for centuries nor do they need to.

We are interested in policy questions, as well as the existence of MOOCs are already calling into question the nature of the university, its structure, its role in society, its accessibility to subpopulations, and its role as a mechanism for providing credentials for its students. The impact of possible certification, changes to the traditional university cost structure, and considerations of access and equity need to be understood in the new world of the MOOCs. Similarly, questions about the relationship between the social context of education beg answering.

In just the few months we have been working with the data from 6.002x, we have come to appreciate what a different animal MOOCs are, and some of the challenges they pose to researchers. The data are more numerous and at a finer grain than have ever been generated from one single course before. The students are more diverse in far more ways—in their countries of origin, the languages they speak, the prior knowledge the come to the classroom with, their age, their reasons for enrolling in the course. They do not follow the norms and rules that have governed university courses for centuries nor do they need to. Although perhaps there are not more instructional components in a MOOC than are available in the typical college course—a statement that can be contended, we suppose—those pedagogies are being used in new ways by a wider variety of people than exist in the average college classroom. All of these factors pose challenges to researchers both in framing the questions they will pursue and the methodologies they will use to answer them. But we are sure the results of research into and the assessment of MOOCs can be of value to course designers, faculty, and other teaching staff, whether they are teaching in a virtual or face-to-face classroom, and we look forward to continuing to contribute to that effort.

References

Angelino, L. M., Williams, F. K., & Natvig, D. (2007). Strategies to engage online students and reduce attrition rates. *The Journal of Educators Online, 4*(2), 1-14.

Coleman, J. S., Campbell, E. Q., Hobson, C. J., McPartland, J., Mood, A. M., Weinfeld, F. D., & York, R. L. (1966). *Equality of educational opportunity.* Washington, DC: U. S. Government Printing Office.

Davidson, C. (2012). What can MOOCs teaching us about learning? Retrieved from http://hastac.org/blogs/cathy-davidson/2012/10/01/what-can-moocs-teach-us-about-learning

Gamoran, A., & Long, D. A. (2008). *Equality of educational opportunity: A 40 year perspective.* In R. Teese, S. Lamb, & M. Duru-Bellats (Eds.), *Education and equity. Vol. 1: International perspectives on theory and policy* (Chapter 1). New York, NY: Springer Press.

Halpern, D. F., & Hakel, M. D. (2003). Applying the science of learning to the university and beyond. *Change*, 37-41.

Hardesty, L. (2012, July 16). Lessons learned from MITs's prototype course. *MIT News*. Retrieved from http://web.mit.edu/newsoffice/2012/mitx-edx-first-course-recap-0716.html

Hart, C. (2012). Factors associated with student persistence in an online program of study: A review of the literature. *Journal of Interactive Online Learning, 11*(1), 19-42.

Seaton, D. T., Bergner, Y., Chuang, I., Mitros, P., & Pritchard, D. E. (2013). Who does what in a massive open online course? *Communications of the ACM.*

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom based practices. *Journal of Engineering Education, 94*(1), 87-101.

Stump, G. S., Hilpert, J., Husman, J., Chung, W. T., & Kim, W. (2011). Collaborative learning in engineering students: Gender and achievement. *Journal of Engineering Education, 100*(3), 475-497.

Lori Breslow is Director of the MIT Teaching and Learning Laboratory (TLL). David Pritchard is a Professor of Physics at MIT and Principal Investigator of the Research in Learning, Assessing and Tutoring Effectively (RELATE) group at MIT. Jennifer DeBoer is a Postdoctoral Associate in Education Research at TLL. Glenda Stump is an Associate Director for Assessment and Evaluation at TLL. Andrew Ho is an Associate Professor at the Harvard Graduate School of Education. At the time of this research, Daniel Seaton was a Postdoctoral Fellow in RELATE; he is now a Postdoctoral Associate in MIT's Office of Digital Learning (ODL). This research was supported by NSF Grant # DRL-1258448.