Making Sense of MOOCs:
A Reconceptualization of HarvardX Courses and Their Students

An Essay Presented

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Contents

Introduction

An odd acronym has dominated discussions of higher education and education technology for the past two years. Massive open online courses, or "MOOCs" for short, captured widespread attention when several of the world's most prestigious universities began doing the unthinkable: offering their educational content for free. In 2012, Harvard and MIT partnered to form edX, a nonprofit platform through which universities across the world could offer MOOCs—online courses deemed "massive" because they have tens or sometimes hundreds of thousands of registrants, and "open" because they are freely available to anyone with an internet connection[1]. In the same year, two computer science professors from Stanford founded Coursera, a for-profit rival to edX that offers courses through partnerships with dozens of universities, including Columbia, the University of Pennsylvania, Princeton, and Stanford. Alongside a third platform known as Udacity, edX and Coursera made MOOCs mainstream. Today, these platforms and their affiliated universities offer MOOCs to millions of students, hailing from every country in the world.

[1] MOOC technology can also be used in ways that are not massive or open—for instance, in hybrid or "flipped" classrooms on brick-and-mortar campuses, where MOOCs replace large lectures so that class time can be dedicated to smaller group discussion and projects. Adequately

Beyond accumulating a remarkably large number of students, MOOCs have become a deeply polarizing subject in both academia and the popular press. Some have argued that these new courses will transform higher education for the better, whether by infusing a stagnant industry with productivity-enhancing technology or by "democratizing"[2] higher education so that high quality learning experiences are available to everyone (Acemoglu et al. 2014; Bowen 2013; Cowen and Tabarrok 2013; Friedman 2013). Others have argued that these courses will harm higher education, whether by restricting in-person learning to an elite few or by promoting impersonal, "industrialized" education more broadly (Carlson and Blumenstyk 2012; Parry 2013; Petriglieri 2013). Still others have argued that MOOCs are little more than an overhyped fad; that these courses represent nothing we haven't seen before in education technology; and that the entire MOOC movement has already peaked (Bady 2014; Tamny 2013). The above list of arguments is not exhaustive, but it readily illustrates the fundamental intensity of this debate over whether and how MOOCs might transform the landscape of higher education.

Though a diverse set of conflicting arguments shapes this debate, these arguments tend to share a common conceptual vocabulary in their understanding of MOOCs. Moreover, this vocabulary is comprised of the same definitions and ideas that are used to describe and evaluate conventional (brick-and-mortar or

[2] Not to be confused with its more political definition, "democratization" in the context of MOOCs typically refers to expanding access to education. This ideal is a frequently invoked by edX President Anant Agarwal, who has argued edX's free courses and open-source software will enable "planet-scale democratization of education" (Rivard 2013b). More formally, in a recent working paper for the National Bureau of Economic Research, Acemoglu et al. (2014) argue that MOOCs will create a more equal distribution of educational resources as well as new opportunities for "lower-skilled" teachers (i.e., those who are not the "superstars" giving MOOC lectures) to provide complementary face-to-face discussions.

traditional online) courses. Concepts like enrollment, attendance, retention, and completion are, often implicitly, treated the same in MOOC contexts as they are in others: for example, enrollment in a conventional course is commonly likened to registration for a MOOC[3]. Yet, it is not clear that these concepts are straightforwardly interchangeable. This view is advanced by DeBoer et al. (2013) and forms the basis for this thesis.

DeBoer et al. (2013) argue that many conventional and widely used educational variables "must be redefined to be useful for description and evaluation of the educational experience in MOOCs." Importantly, the authors distinguish between redefining by *reoperationalization*—updating a variable's operational definition without changing its uses and interpretations—and redefining by *reconceptualization*—updating both a variable's operational definition and its intended uses and interpretations. Current discussions and evaluations of MOOCs, the authors argue, tend to invoke reoperationalization rather than reconceptualization.

This thesis explores the degree to which the MOOC debate would benefit from the reconceptualization of fundamental metrics and concepts. Ultimately, this thesis argues that MOOCs cannot be properly understood using conventional educational metrics and definitions, and that students, instructors, university leaders, and policymakers must be wary in viewing this new technology through the lenses of the past. By contextualizing MOOCs within a rich history of distance

[3] For a particularly recent example, consider Guerriero (2014), who equates registration with enrollment in a MOOC when writing, "An average of only four per cent of registered users finished their MOOCs in a recent University of Pennsylvania study, and half of those enrolled did not view even a single lecture."

learning technologies—ranging from nineteenth-century correspondence courses to present-day OpenCourseWare—we can identify the aspects of MOOCs most relevant to this debate as well as the ways MOOCs might be materially different from their technological predecessors. In particular, this context motivates explorations of retention[4] and asynchronicity[5] as issues critical to our understanding of MOOCs. Student retention, I will argue, determines the societal value we ascribe to these courses and ought to be reconceptualized with reference to more modular metrics that account for the ways students can have meaningful educational experiences in a MOOC without "completing" it by earning a certificate. Asynchronicity, I will argue, shapes the way we understand what it means to be a student, and thus the idea of a "student" ought to be reconceptualized with broader categorizations that account for the diverse paths students take through these courses. In short, MOOCs represent a fundamental departure from current and past educational models, and as a result, we need to change the way we think about what "courses" and "students" are.

Contributions

This thesis makes two major contributions to existing scholarship. First, this thesis challenges common assumptions about what MOOCs are and how they

[4] Retention corresponds to the fraction of students who complete a course. In conventional educational settings, this is calculated as the number of graduates or course passers divided by the number of students who enrolled.

[5] Asynchronicity refers to students being "out of sync" with each other in a course. In conventional educational settings, students typically meet at the same time and place and progress at the same pace. This kind of course would be characterized as "synchronous." Many distance learning courses, on the other hand, allow students to engage at different times, places, and paces; this kind of course would be characterized as "asynchronous."

engage with students. These assumptions permeate a debate of enormous importance for students, instructors, university leaders, and policymakers alike. Hundreds of universities are already investing large sums of money to develop these courses, often for the sake of experimentation and the fear of being left behind.[6] As college tuition continues to rise faster than inflation—a perennial problem lambasted in, for instance, President Obama's 2012 State of the Union Address—prominent economists like William Bowen have pointed to technology as a potential way to reverse this trend (Bowen 2013). Alongside these rising costs, Avery and Turner (2012) find that the high economic returns to college have contributed to a rising college wage premium[7] over the past 30 years. The confluence of these factors pressures students to pursue college degrees even at the expense of incurring burdensome debt, and it particularly pressures public institutions to raise tuition in the face of sharp cutbacks in state funding (Avery and Turner 2012; Ehrenberg 2012; Deming et al. 2012). Because there is a chance that MOOCs may help ease these pressures and the resultant inequities by making higher education more accessible, it is important that we understand these courses properly. But the importance of this debate is more than economic. As evidenced

[6] It is telling, for instance, that Harvard and MIT each put up $30 million to launch edX, without a sustainable revenue model in place. These courses are not inexpensive to produce: the Distance Learning Committee at Cornell estimates that edX MOOCs "cost around $70,000 in non-faculty costs and take . . . 200-300 hours to produce" (Grinspoon 2013). At the same time, the Babson Survey Research Group's most recent annual report on the state of online learning in U.S. higher education finds that the most common objectives cited by MOOC-offering institutions are "increasing the visibility of the institution," "driving student recruitment," "experimenting with innovative pedagogy," and "providing more flexible learning opportunities" (Allen and Seaman 2013). The survey also reports that more than half of U.S. higher education institutions are "undecided" in their plans to pursue MOOCs. There is, in short, an abundance of uncertainty accompanying the hype and investment in this technology.

[7] The college wage premium refers to the additional wages received by college graduates, relative to high school graduates, on average. An increasing college wage premium means college graduates are earning more relative to those without a degree.

by the extensive media coverage and deep philosophical qualms voiced by, for instance, the San Jose State Philosophy Department[8] or the majority of Amherst College's faculty[9], there is widespread interest and concern about how MOOCs may change the higher education experience—both on campus and off. The outcome of this debate may have profound implications for the students and instructors of the future, and as a result, today's analyses obtain heightened importance. By clarifying common misconceptions and providing reconceptualized alternatives, this thesis will contribute to the validity and power of these analyses, addressing gaps in a literature that has not sufficiently reconceptualized key concepts for the MOOC context.

The second contribution of this thesis stems from its original empirical analyses on novel datasets, offering new insights for Harvard's MOOC program in particular. I have spent nearly nine months working closely with the HarvardX and MITx research teams (HarvardX and MITx are the divisions of Harvard and MIT dedicated to producing and researching MOOCs on the edX platform), helping clean, explore, and interpret the gigabytes of student data produced by these courses each week. In helping these teams streamline their data processes, I have become intimately familiar with these courses as well as their data and the

[8] In the spring of 2013, San Jose State University (SJSU) contracted with edX to integrate a Harvard MOOC, Michael Sandel's JusticeX, into an introductory SJSU philosophy course. The SJSU Department of Philosophy refused to do so and published an open letter to Professor Sandel, arguing that MOOCs at public universities represent "a serious compromise of quality of education and, ironically for a social justice course, a case of social injustice." The full text of this letter can be found at http://chronicle.com/article/The-Document-an-Open-Letter/138937/.

[9] Likewise in the spring of 2013, the Amherst College faculty rejected an invitation for Amherst to join edX. In subsequent interviews with *Inside Higher Ed*, many of these professors questioned whether MOOCs were "compatible with Amherst's mission to provide education in a 'purposefully small residential community' and 'through close colloquy'" (Rivard 2013a). The faculty also expressed fears over the possibility that Amherst MOOC certificates of completion would dilute the value of an Amherst degree.

assumptions behind them. This perspective and access has enabled me to derive custom datasets that are unusually rich and detailed for MOOC analyses. Particularly with regard to estimates of time-spent[10] and visualizations of asynchronicity, this thesis offers many metrics and figures that are, to my knowledge, unique. It is my hope that these ideas will complicate existing research, inspire new analyses, and offer professors and course staff insights they may not otherwise have had.

Before continuing, I should clarify what this thesis is not. Though a quantitative work, this thesis uses data and visualization for illustrative purposes; I do not use statistical models to make causal inferences because my HarvardX datasets are observational, and the capacity to run experimental "A/B" tests is still under development at edX. My methods are, thus, descriptive rather than inferential. This thesis also spans a wide range of educational topics, many of which are controversial, and it would be impossible to adequately address all of them. To focus my argument, I will ignore many rich but peripheral and ultimately inconclusive issues like, for example, whether MOOCs can offer learning quality comparable to that of brick-and-mortar courses.[11] Finally, this thesis generally cannot offer definitive conclusions—MOOCs and the surrounding literature remain immature and are evolving quickly. What we call a MOOC today may be completely different in five years, and undoubtedly this technology's development will take unforeseeable turns. What this thesis pursues

[10] See Appendix B for a technical explanation of "time-spent," which refers to the amount of time students spent in various parts of the course.
[11] The short answer is that we do not have compelling evidence one way or the other. For longer answers, see Bowen (2013) and Lack (2013).

is a more accurate and meaningful understanding of MOOCs today so that students, instructors, university leaders, and policymakers can make informed decisions to shape the best possible educational future.

Data and Methodology

This thesis examines student data from a handful of early HarvardX MOOCs spanning the humanities and health sciences. These MOOCs are all adaptations of introductory Harvard courses taught on campus (detailed in Appendix A). Briefly, they include "CB22x: The Ancient Greek Hero" (two separate runs of the same course, hereafter, "HeroesX" and "HeroesX #2"); "ER22x: Justice" (hereafter, "JusticeX"); "PH207x: Health in Numbers: Quantitative Methods in Clinical & Public Health Research" (hereafter, "Health in Numbers"); "PH278x: Human Health and Global Environmental Change" (hereafter, "Human Health"); and "SW12x: China (Part 1)" (hereafter, "ChinaX"). These courses represent the HarvardX MOOCs offered before the end of 2013 that had the most complete data. Of these courses, I will most frequently turn to HeroesX because its information is the most complete.

The data in this study come from a variety of sources. The richest sources of data are the "clickstream" tracking logs, which record every click, page view, and interaction a user has while logged into a HarvardX course. For an entire course, these log files can be as large as ten gigabytes. A second source of data comes from course SQL tables containing student status, progress, and demographic information. The third source of data comes from course discussion

forums, and the final source of data comes from pre-course Qualtrix surveys given to several hundred students before HeroesX #2 and ChinaX. Much of my research effort was spent compiling, merging, and deriving new feature sets from these data sources using a large number of Python scripts, some of which have been made open source on Github.[12] The amount of data contained in these courses is quite large, so many of these calculations took hours to process and required considerable debugging.

Looking Ahead

The body of this thesis is divided into three chapters. In the first chapter, I review the lengthy history of distance learning, beginning with 19th century correspondence courses and ending with a detailed examination of MOOCs vis-à-vis other online learning technologies today. This context illustrates how MOOCs are both similar and different from their technological predecessors. In particular this chapter identifies retention and asynchronicity as critically important issues that are distinctly pronounced in MOOCs. These two issues form the basis for the subsequent two body chapters.

In the second chapter, I review the theoretical and empirical literature on student retention in higher education, distance learning, and MOOCs more specifically. I show how retention is closely tied to the way we value these courses, and that the way we currently measure retention in MOOCs—using registration-based certification rates—is frequently more misleading than

[12] See, for example, the HarvardX-Tools repository at https://github.com/jimwaldo/HarvardX-Tools.

meaningful. I then reconceptualize retention in MOOCs by developing more modular measures of retention that allow us to capture some of the valuable educational experiences students can have without earning certificates.

Finally, in the third chapter I review the theoretical connections between and importance of asynchronicity, interactivity and openness in MOOCs. I argue that these characteristics fundamentally shape the student experience, and that existing approaches to defining and categorizing MOOC students often ignore the important and diverse pathways students take through these courses. I introduce new measurements of these asynchronous pathways in an effort to begin reconceptualizing the idea of "students" in MOOCs.

Chapter One
MOOCs in Historical Context

Despite the widespread attention they have received in popular media, MOOCs emerge from a type of schooling—distance education[13]—that is hardly new. To understand the extent to which MOOCs might transform higher education today (the "MOOC debate"), we need to understand how MOOCs advance beyond their historical predecessors. To that end, this chapter reviews the history of distance education, beginning with its roots in nineteenth century correspondence courses and ending with its latest iteration in the form of MOOCs. We will define distance education as "planned learning that normally occurs in a different place from teaching" and "aims to provide instruction in places and times that are convenient for learners rather than teachers or teaching institutions" (Moore and Kearsley 1996). We will trace the evolution of distance education across five technologically defined "generations" identified by Moore and Kearsley (1996) and adopted by much of the subsequent literature (Passerini and Granger 2000; Kember 2007): correspondence, broadcast radio and

[13] In this thesis, "distance education" and "distance learning" will be treated as synonymous.

television, open universities, teleconferencing, and online education. In particular, we will closely examine the present generation of internet-based distance education—traditional online education, OpenCourseWare, and MOOCs—and conclude with a detailed description of edX, the MOOC platform explored in this thesis.

Tracing these generations of distance education will elucidate the aspects of distance learning most relevant to the broader MOOC debate as well as the ways MOOCs may be distinct from their technological predecessors. Specifically, this chapter identifies retention and asynchronicity as critical issues in distance learning that are distinctively acute in MOOCs. Retention—a measure of how well courses are able to hold on to their students—is often problematically low in distance education, and early evidence suggests that MOOCs have substantially lower rates of retention. As will be addressed in Chapter Two, retention is important to the MOOC debate because measures of retention help determine the societal value we ascribe to different forms of learning. Asynchronicity—a concept encapsulating the degree to which students progress at different times, places, and paces—is often a distinctive feature of distance education, and the massively open nature of MOOCs suggests that asynchronicity might be even more pervasive and pronounced in these courses. As will be discussed in Chapter Three, asynchronicity impacts the MOOC debate by fundamentally altering the way we conceive of "students." Beyond retention and asynchronicity, however, the generations of distance education reviewed in this chapter contextualize MOOCs within a rich history of ideas, projects, and debates that dispel the notion

that MOOCs emerged without precedent. Thus contextualized, MOOC scholarship must engage in a delicate balancing act, learning from the past while simultaneously challenging its applicability.

Correspondence Courses

University-level correspondence education originated in nineteenth century Britain at a time when higher education was largely restricted to aristocrats (Watkins and Wright 1991). In 1857 and 1858, Oxford and Cambridge bolstered a rising "university extension" (i.e., "correspondence study") movement by offering courses with distributed written course materials and local exams—innovations aimed at making university instruction available to a broader audience (Ibid.). These offerings marked the start of the first era of distance education, which by the early twentieth century had spread to universities across Europe and the United States. Evidenced by a 1920 bulletin by U.S. National University Extension Association Executive Secretary Arthur J. Klein, correspondence courses continued to be seen as a powerful way to expand access to higher education while "lack of means, ill health, family or social duties, business, and the necessity of earning a living entirely prevent a large proportion of the people from attending schools" (Klein 1920).

While correspondence courses took many forms, this kind of education fundamentally involved printed or written materials delivered asynchronously by mail. Printed material generally consisted of customized textbook excerpts, lesson outlines, and exercises; students would mail their completed assignments to

instructors, and instructors would mail their feedback to students (Passerini and Granger 2000). This mail-mediated coursework was both slower and less interactive than comparable on-campus offerings, but this asynchronicity gave students direct control over the location, time, and pace of their formal learning for the first time. Despite sacrificing face-to-face interaction, correspondence courses maintained a degree of personalization comparable to that provided in traditional courses because instructors still provided individualized comments and feedback on students' written work. Ultimately, correspondence courses were just traditional courses with a new, asynchronous delivery medium—admissions, tuition, and university credit were still essential to this kind of education.

Insofar as their purpose was to expand access to education in the United States, correspondence courses were successful but hardly transformative. As of 1920, 73 postsecondary institutions across 29 states offered correspondence courses (Watkins and Wright 1991). Of these correspondence programs, the University of Wisconsin was the most successful, tallying 33,659 vocational enrollments and 14,989 academic enrollments[14] in 1920 (Ibid.). However, Wisconsin was exceptional; while the University of Kansas's correspondence study department was likewise among the most successful and grew rapidly from 57 registrants in 1909 to 1,373 registrants in 1918 (Klein 1920), it had nowhere near the enrollment figures of Wisconsin and reflects a steep drop in the levels of success achieved across institutions. As noted by Watkins and Wright (1991), "Kansas was not Wisconsin," and like most other institutions building such

[14] Correspondence courses became increasingly oriented toward vocational learning: by 1926, roughly 80 percent of correspondence students across the United States took vocational courses (Noffsinger 1926).

programs, the school was far more cautious and conservative in its extension efforts. The hearts of all universities were still firmly situated in their residential programs, evidenced by the fact that nearly all higher education institutions limited the number of correspondence credits that could be applied toward a degree to between 25 and 50 percent (Ibid.). As reflected in Bramble and Panda (2008), most universities treated correspondence education as a "marginal enterprise." In a study of 75 schools, Noffsinger (1926) found "inordinately high" dropout rates—close to 97 percent—in correspondence courses; such findings may have contributed to the widespread reluctance to embrace correspondence learning. Moreover, while tuition and enrollment fees for correspondence courses were comparatively lower (typically one to eight dollars per credit), these costs were still identified by Klein as detrimental to the overall pursuit of democratized education: "When fees are charged for correspondence study a large proportion of those who might serve the world with better productive force, with greater intelligence, with more complete understanding, are condemned to go through life only half men" (Klein 1920). In short, correspondence courses grew powerfully at a select few schools but had a limited impact at most higher education institutions. They did little to displace the firmly rooted focus on residential education, and they did not change the way most students received education.

Broadcast Radio and Television

The inventions of broadcast radio and television generated considerable excitement and even hype among proponents of distance education, but ultimately

they proved even less impactful than correspondence courses. The first commercial radio stations received broadcast licenses in the early 1920s. By 1936, more than two hundred colleges, universities, school boards, and proprietary schools had received such licenses, and many offered radio courses for credit (Pittman 1986). The transformative potential of the new broadcasting technology was quickly identified by higher education institutions; indeed, the University of Iowa's request to the Federal Radio Commission argued, "…it is no imaginary dream to picture the school of tomorrow as an entirely different institution from that of today, because of the use of radio in teaching" (Ibid.). Likewise, a 1924 article on "The Future of Radio Education" in the *Journal of the National Education Association* predicted that radio broadcasting would "become a great free common school in the not distant future—a common school with classes numbering thousands" (Ibid.). Yet for all this promise, instructional radio was an utter failure, and by 1940 it had all but disappeared from the airwaves.

The first public television broadcasts occurred in the late 1920s, and by 1939 the University of Iowa's television station had broadcast nearly four hundred educational programs (Moore and Kearsley 1996). Television courses, or telecourses, were usually designed by teams of specialists, licensed to colleges and universities, and then either broadcast on local cable channels or mailed as cassettes to students enrolled in university extension programs (Ibid.). Although some postsecondary institutions offered testing and credit for students taking telecourses, most institutions made little use of broadcasting, and there was often

little material incentive for students to "complete" one of these courses (Kember 2007). Like radio, investments in broadcast television courses were short-lived.

As noted by Kember (2007), the reasons for the failure of radio and television broadcasting in higher education were largely economic: frequency bands and channels were expensive, scarce, and aggressively targeted by the entertainment and advertising industries, which crowded out educational programming. Moreover, the unidirectional mode of instruction was too unpopular with students to achieve significant scale. Courses and instruction offered via broadcasting were entirely lacking in personalization and interactivity: everyone received and completed the same thing. And though these courses were accessible by anyone with a radio or television, radio ranges were limited—for example, in 1931 the University of Iowa's radio station had a range of 100 miles (Ibid.). In effect, these courses allowed less asynchronicity than correspondence courses—students could engage from different locations, but they still had to tune in within range during broadcast times—and this relative inflexibility was not balanced with more individualized student-instructor attention. In the end, these courses did not catch on with students, and competing for bandwidth and programming time proved too costly for schools to create sustainable programs.[15]

[15] While broadcast television and radio faded into obscurity in higher education in the United States, these technologies would later achieve a sizeable presence in Mexico through the *Telesecundaria* system, a nation-wide distance learning program that began in the late 1960s in an effort to expand access to secondary education. To combat a shortage of teachers at secondary schools—particularly in rural areas—Telesecundaria offered televised instruction at local community facilities "to *complement* rather than reform or replace the traditional secondary schools" (Mayo et al. 1975). In 1968, the program's first year, 6,500 students enrolled; by 1971, enrollments had grown to nearly 30,000; and by 2000, more than a million Mexican secondary school students were enrolled in the program, accounting for 16 percent of 7th, 8th, and 9th grade enrollment across the country (Calderoni 1998).

By themselves, these technologies were too primitive to have a profound impact on higher education.

Open Universities

The 1960s and 1970s saw the birth of open universities, which for the most part involved new institutions rather than new technologies. The British Open University (BOU), originally dubbed the "University of the Air," was the first and most successful of these institutions dedicated exclusively to distance education, and it became a model for a scattering of imitations in the United States, like New York's Empire State College (Watkins and Wright 1991). Unlike the correspondence, radio, and television programs and courses offered in prior decades, the BOU combined many different kinds of media in its course packages (Kember 2007). Thus, the BOU adopted correspondence methods of delivery and assessment, but used audio, visual, and later computer media in addition to printed material. But perhaps most significantly and distinctively, open universities were based on principles of openness (nearly anyone could enroll in any course, regardless of qualifications) and asynchronicity (students could usually start a course at any time), while offering further student support through tutoring and counseling programs (Moore and Kearsley 1996). In contrast to correspondence courses, where individual professors developed their course materials, teams of experts developed the course materials at open universities. Altogether, open universities were institutions far more dedicated and comprehensive in their approaches to distance education than systems of the past.

Open universities were successful in the sense that they reached far more students than did prior forms of distance learning; on the other hand, large enrollments also made high dropout rates a more salient problem than it had been in the past. National in scope, the BOU enrolled 24,000 students in its inaugural class in 1971, and by 1996 it had 130,000 students taking courses each year (Moore and Kearsley 1996). Alongside these large enrollments, personalized tutoring and mentoring remained crucial supplements to the correspondence-style feedback on assignments. At the BOU, this student support was made possible by the employment of 5,000 part-time tutors and counselors on top of the 2,800 full-time staff members, all spread across 13 regional and 250 local learning facilities throughout Great Britain (Ibid.). But even with these support systems, retention was a key problem from the start: in 1971 and 1972, roughly 40 percent of BOU students dropped out before end-of-year examinations (Lumsden and Ritchie 1975). Future studies found these high dropout rates to be a persistent trend in open universities like the BOU (Simpson 2003). Nonetheless, the open university model proved to be the most successful distance learning implementation to date—particularly in the United Kingdom, where the BOU continues to operate today—and it provided a key foundation for the online courses and schools of the future.

Teleconferencing

Although the BOU was successful in the United Kingdom, the predominant model of distance education in North America revolved around two-

way teleconferencing at universities not solely devoted to distance learning (Kember 2007). In contrast to open university and correspondence models, which were oriented around a course package of materials, and broadcasting models, which were based on one-way communication, teleconference courses delivered all content through audio or visual communication where students could interact with their instructors (Ibid.). In this way, teleconference courses were most similar to traditional face-to-face offerings at residential or brick-and-mortar institutions.

Teleconference courses, however, have had a limited impact in expanding the role of distance learning in higher education. By 1996, only 15 percent of schools with distance education programs actually put these courses in their curricula (Hashim and Jaafar 1999), and according to the U.S. Department of Education (2011), even by the 1999-2000 academic year only eight percent of U.S. undergraduates were enrolled in a distance education course and only two percent were enrolled in a distance degree program. Part of the limited scope of teleconference courses is by design: because these courses involve two-way communication like face-to-face courses, individual professors cannot meaningfully interact with massive volumes of students. Likewise, given the state of pre-internet teleconferencing technology, students were often restricted to designated locations and times in order to have access (Kember 2007). Thus limiting students' abilities to engage asynchronously—that is, whenever and wherever they pleased—these courses offered little that traditional lecture courses could not. Moreover, as Kember (2007) notes, "the lack of need to adapt the

classroom style of teaching meant that there was no need to reflect upon the nature of teaching and limited opportunities for educational developers to present alternatives." Rather than being revolutionary, teleconference courses represented just another stepping stone toward the more impactful rise of online education.

Online Education

The technological hallmark of modern and large-scale distance education is, of course, the internet. Advances in network speeds, broadband availability, and content hosting technologies have enabled a rapid expansion in online distance education since the early 1990s. Although Moore and Kearsley (1996) treat online distance education as a singular category, three sub-trends stand out today within this "generation" of distance education: 1) the steady rise of online campuses and schools; 2) the more recent OpenCourseWare movement; and 3) the current proliferation of MOOCs and MOOC platforms.

Online Campuses and Schools

Though online education is often considered a recent invention, the first online campuses and schools began appearing in the 1990s. A quick review of the websites for several of today's best-known brands in online higher education reveals the birth of this new era: the University of Phoenix's Online Campus, the largest for-profit online education institution, was established in 1989; Jones International University, the first fully-online university, was founded in 1993 and first regionally accredited in 1999; and Western Governors University, the largest

nonprofit and the only NCATE (National Council for Accreditation of Teacher Education) accredited fully-online university today, was founded in 1997. The number of schools and campuses dedicated to online distance learning began to grow more rapidly in the mid-2000s, as did enrollments (total 12-month enrollment at the University of Phoenix's Online Campus, for instance, grew from 46,128 in 2001 to 442,033 in 2012, according to data from the Integrated Postsecondary Education Data System, a national database maintained by the U.S. Department of Education). But perhaps the most telling evidence for the impact of online learning comes from Allen and Seaman (2012), which found that by 2012, nearly a third of all enrollments at degree-granting postsecondary institutions were online and nearly two-thirds of all higher education institutions offered complete online degree programs. Although brick-and-mortar institutions continue to dominate the landscape today, schools in the online space boast the largest enrollment counts across all of higher education.

These "traditional" online education institutions often contain a mix of synchronous and asynchronous elements, allowing for many different types of interaction with the course. At the University of Phoenix Online, for example, students not only communicate with other students, instructors, and academic counselors through online forums and chat rooms, but also work in small "Learning Teams" to complete group projects. To keep students on the same trajectory, course policies often require students to check in regularly and adhere to weekly schedules. Recently, the University of Phoenix and other online for-profits have also begun investing in "adaptive learning" technologies—software

that uses student data and machine learning to, in theory, automatically tailor course material to individual student needs.[16] Adaptive technologies may help mediate distance education's tension between asynchronous learning on the one hand and personalized or interactive learning on the other, but it remains too early to draw definitive conclusions on the efficacy of these new approaches. What we can say about traditional online courses is that they are generally more asynchronous than their brick-and-mortar counterparts, but not so asynchronous that they lack structure.

As with open universities, retention is a critical issue for online schools. Data from the U.S. Department of Education show that in 2009, the top ten online institutions had an average retention rate among first-time (i.e., non-transfer) full-time students of 55 percent versus a national postsecondary institution average of 77 percent, and an average retention rate among first-time part-time students of 39 percent versus a national average of 46 percent (Burnsed 2010). These figures do not distinguish between the many different kinds of schools and degree programs (public and private; two-year and four-year; certificate, associates, bachelors, and masters; etc.), but they have drawn widespread concern. In a nationwide survey in 2012, for instance, academic leaders at nearly three-quarters of all postsecondary institutions identified low retention rates in online courses as a barrier to the growth of online instruction (Allen and Seaman 2013).

For most online schools, high student loan default rates also represent a critical issue that limits the transformative power of the sector. With the exception

[16] For example, if a student answers a complicated math problem incorrectly, an adaptive learning program could infer the precise concept that confused the student, and then display a new problem or hint that emphasizes that concept.

of Western Governors University, the majority of large-scale online schools—like the University of Phoenix, Kaplan University, Strayer University, and Ashford University—are for-profit institutions that derive most of their revenues from federal loans and grant money. The most recent default rate statistics published by the U.S. Department of Education found that "for-profit institutions continue to have the highest two- and three-year cohort default rates at 13.6 percent and 21.8 percent, respectively. Public institutions followed at 9.6 percent for the two-year rate and 13 percent for the three-year rate. Private non-profit institutions had the lowest rates at 5.2 percent for the two-year rate and 8.2 percent for the three year rate."[17] Annual reports from notable online for-profits reveal that these schools have student loan default rates that are likewise well above average—the University of Phoenix, for instance, had a three-year cohort default rate of 26 percent.[18] Moreover, Deming et al. (2012) find that the higher student loan default rates at for-profits cannot be explained by demographics and socio-economic status alone, suggesting that the economics of the for-profit model itself may be problematic in practice. These high default rates undermine arguments that traditional online schools are expanding access to higher education, and today they offer a striking juxtaposition with MOOCs, which are generally free to students.

[17] U.S. Department of Education, "Default Rates Continue to Rise for Federal Student Loans," September 30, 2013, accessed February 28, 2014, http://www.ed.gov/news/press-releases/default-rates-continue-rise-federal-student-loans.
[18] This figure comes from the Form 10-K filed by Apollo Education Group (which owns the University of Phoenix) with the Securities and Exchange Commission (SEC) for fiscal year 2013. The filing is available on EDGAR Online.

The OpenCourseWare Movement

With a front-page article in the *New York Times* on April 4, 2001, the Massachusetts Institute of Technology made an ostensibly bizarre announcement: over the next decade, the university would make the syllabuses, lecture notes, lecture videos, problem sets, and exams for its entire two thousand course catalogue freely available online through an initiative known as MIT OpenCourseWare (MIT OCW) (Goldberg 2001). Indeed, according to monthly reports available on the MIT OCW website, by April 2011 the site had published 2,057 courses and was receiving more than a million unique visits per month from around the world. While MIT OCW was originally intended to provide resources for educators, surveys show that most of its users are in fact students and self-learners who use the site to complement coursework, expand personal knowledge, and explore extra-professional interests (Walsh 2011).

One can argue that MIT OCW has been successful on a number of levels. It provided educational resources to millions who otherwise would not have had access to them; it garnered worldwide respect and appreciation for the MIT brand; and it spawned a broader movement of smaller imitators that culminated in 2008 with the formation of a global OpenCourseWare Consortium with hundreds of member institutions, including the African Virtual University, China Open Resources for Education, Open University Netherlands, and the Universidad Politecnica Madrid. Yet the most meaningful effects of the OpenCourseWare movement may lie in the broader discourse it fostered. While for-profit online universities continued to pursue revenues driven by federal loans and grants,

OpenCourseWare pointed discussions of online education in an entirely different direction: open and free. These principles would become the foundation for MOOCs, so today one can argue that OpenCourseWare's most significant contribution to online learning has been more ideological than technological.

Despite these successes, OpenCourseWare has not transformed higher education. In a 2008 interview with Walsh (2011), Ira Fuchs, who oversaw the Mellon Foundation's funding for MIT OCW, suggested, "If you take away OCW completely, I'm not sure higher education would be noticeably different." OpenCourseWare simply publishes static educational resources: by design, it does not confer certificates or degrees; it does not offer personalized feedback; and it does not allow for any interaction between students, asynchronous or otherwise. As a result, OpenCourseWare faces a challenge in differentiating itself from other free online knowledge resources like Wikipedia, Wolfram Alpha, or Khan Academy. By stopping short of actually running interactive courses and offering certification, OpenCourseWare did not encroach upon the space of traditional online schools and instead provided a logical stepping-stone for the next phase of online higher education: massive open online courses.

Massive Open Online Courses

While there is some debate, most pinpoint the birth of MOOCs at the Fall 2011 launch of a graduate-level Stanford course called "CS221: Introduction to Artificial Intelligence." This course, run by Dr. Sebastian Thrun who was at the time a professor of computer science at Stanford University, was more than

OpenCourseWare: it had a distinct duration, it provided tools for students to interact with each other, and it awarded certificates to completers. It was also distinct from traditional online education: no course credit was offered, it was freely available to anyone who registered, and the final enrollment tally exceeded 150,000 people. Although other breeds of "MOOCs" had arguably run as early as 2008 at smaller scales and with more emphasis on social knowledge creation, this course was what started "the revolution that has higher education gasping" (Pappano 2012). Indeed, the year following the launch of Thrun's course saw the creation of hundreds of MOOCs across virtually all academic subjects, the emergence of three large MOOC platforms to produce and host these courses, and the large-scale participation of top universities from around the world, including the entire Ivy League, the California Institute of Technology, Duke, Stanford, and many others. The rise of MOOCs happened very quickly (Lewin, 2013, notes that the largest MOOC platform, Coursera, grew to a million users faster than either Facebook or Twitter), and this impressive growth continues to accelerate today.

Today, three MOOC platforms dominate the space: Coursera, founded by Stanford computer science professors Andrew Ng and Daphne Koller; edX, founded as a joint partnership between Harvard and MIT; and Udacity, founded by Thrun following the success of his pilot course on artificial intelligence. Each of these platforms was established in 2012, and while they are all similar in that they offer MOOCs, there are important philosophical differences that set them apart. In terms of funding, Coursera and Udacity are venture-backed for-profit companies, whereas edX is a not-for-profit partnership. While Coursera and edX

offer courses developed by dozens of prominent universities, Udacity develops its courses in-house and through corporate sponsorships (for example, Udacity has offered a course on web app development taught by employees from SalesForce, a cloud computing company). In addition, while Coursera and edX offer courses across nearly all fields of study, Udacity focuses exclusively on business, math, and science per its orientation towards career building and employment. Coursera is by far the largest of these platforms, reporting in an October 2013 blog post that it had 107 institutional partners, 532 courses, and 5.2 million users. But despite these differences in funding, institutional backing, and academic focus, all three of these platforms emphasize a primary mission dedicated to broadening access to education.

The MOOCs offered across these platforms have similar structure. The primary medium for instruction is the lecture video; typically, longer lectures are broken up into smaller topical chunks (often as short as five or ten minutes) with interspersed quiz questions. Students are assessed through a combination of problem sets and exams, where questions are generally formatted as either multiple choice or short answer. These courses also feature discussion forums for users to interact with professors, course assistants, and other students. Additionally, some courses will offer live videoconferences with professors or organize optional in-person meetings between students in the same geographic area. While students who pass a course receive certificates of completion, by and large these courses carry no formal institutional course credit. Thus, a certificate of completion for a Harvard MOOC does not count for course credit at Harvard.

The structure of MOOCs emerges as a natural combination of its immediate predecessors: traditional online education and OpenCourseWare. Like traditional online education, MOOCs are structured, interactive, and graded; like OpenCourseWare, MOOCs are free, all-inclusive, and massive. MOOCs also inherit key challenges from these predecessors: from traditional online education, high dropout rates, and from OpenCourseWare, an unwieldy, asynchronous global audience. Though they reflect the past, however, these key challenges appear to be more pronounced in the MOOCs offered today. Whereas year-over-year retention rates in traditional online schools are typically between 40 and 55 percent, MOOCs consistently have retention rates of 5 to 10 percent of registrants for a *single course*. And whereas OpenCourseWare enables open access to simple collections of educational resources, MOOCs apply the same principles of openness and asynchronicity to live courses that rely on notions of enrollment, completion, attendance, and participation. In light of these stark and fundamental differences, the coming chapters will consider carefully whether these challenges take on new meanings in the context of MOOCs.

The edX Platform

Because edX MOOCs are the subject of this thesis, I will briefly elaborate on the platform's basic structure and specific history. EdX formed in 2012 as a partnership between Harvard and MIT, and as of November 2013 it had grown into a global partnership of 29 higher education institutions collectively known as the XConsortium. Beyond Harvard and MIT, XConsortium members include the

University of California, Berkeley; Caltech; Cornell University; Berklee College of Music; Seoul National University; Kyoto University; Peking University; the University of Queensland; and others. These institutions develop MOOCs using edX's tools and with edX's assistance, but these courses belong to their respective institutions. Thus, while the overall project is a collaborative enterprise, it is important to distinguish between edX and the member of the XConsortium—edX itself is a separate institution tasked with developing and running the underlying platform, while XConsortium members are higher education institutions like Harvard and MIT that develop, run, and analyze their own courses through internal "HarvardX" and "MITx" divisions. In short, edX hosts and develops the platform, while XConsortium members develop and run their own courses.[19]

Like Coursera and Udacity, edX began with a technical course. This pilot course was an online version of MIT's "6.002x: Circuits and Electronics" and was taught by Anant Agarwal, who is also the president of edX. More than 150,000 students spanning nearly every country in the world registered for the course. Since then, edX has launched more than a hundred courses and garnered more than 1.6 million users. While HarvardX and MITx were responsible for most of the early courses, edX's catalogue has expanded to include many courses from each of its institutional partners.

According to its website, the edX platform was established with three goals: 1) to "expand access to education for everyone"; 2) to "enhance teaching

[19] Apple's "App Store" is a helpful analogy for understanding the relationship between edX and the XConsortium member institutions. Like Apple, edX has built and maintains a platform; and like app developers, XConsortium member institutions develop "apps" or courses that run on the platform.

and learning on campus and online"; and 3) to "advance teaching and learning through research." Pursuant to these ideals, the platform is not-for-profit, with 501(c)(3) status pending, and open source, which means its source code is openly available online and anyone is welcome to contribute. Additionally, edX makes large troves of course and student data available for academic research—a feature that greatly benefited this study.

Summary

This background chapter reviews the extensive history of distance education, from its origins in nineteenth century correspondence courses to present-day MOOCs. We have seen how various technological developments—including radio, television, and internet—have advanced the field of distance education but largely failed to meet the hype that they would radically transform higher education more broadly. Situated within this historical narrative of distance education, the MOOC era clearly has just begun, but it is well worth asking whether this technology, too, will succumb to overblown expectations. MOOCs face many of the same challenges that continue to plague both traditional online schools and OpenCourseWare, and whether the MOOC model can be more than the sum of its parts will rest in large part on whether it can address these challenges. These challenges, thus, are important factors in the debate over MOOCs' transformative power.

At the same time, early evidence and basic intuition suggest that the unique combination of principles that define MOOCs may render these courses

materially different from their technological predecessors. In particular, while varying degrees of asynchronicity have been present throughout the history of distance education, MOOCs combine the complete asynchronicity of OpenCourseWare with assessments, certification, and other elements from traditional courses. Likewise, while low retention has been criticized across many "generations" of distance education, the issue appears to be decidedly more acute in MOOCs, where massive numbers of registrants are accompanied by similarly massive numbers of dropouts. MOOCs may be reflective of the past, but because they represent a combination of distance learning technologies and ideologies that seems to be more than superficially distinct from those of the past, we should consider carefully whether the whole is different from the sum of its parts. This consideration motivates the investigations of the next two chapters, where I will argue that the ideas of retention and asynchronicity must indeed be reconceptualized for accurate interpretation in the MOOC context.

Chapter Two
Reconceptualizing Retention in MOOCs

Low student retention[20] is a common problem in distance learning; indeed, low retention is perhaps the leading criticism of MOOCs, where roughly 95 percent of students who register fail to earn a certificate of completion. In any higher education context, retention is an important metric because it shapes our understandings of success and educational value. This is one reason why graduation rates[21] are so carefully monitored by educational leaders and policymakers, and why a recent opinion piece by the *Daily Texan* Editorial Board identified the low completion rates and high costs of University of Texas MOOCs as telltale numbers that "don't bode particularly well for the courses' overall success" (Daily Texan Editorial Board 2014). However, while retention rates in

[20] A number of terms related to retention are used throughout the literature and will be used throughout this chapter. *Retention* rates, *completion* rates, *pass* rates, and *certification* rates refer to the fraction of students who successfully complete a course. *Attrition* rates and *dropout* rates refer to the fraction of students who fail to complete a course. Each of these rates necessarily involves both a numerator (the number of students who achieve a particular outcome, like passing or earning a certificate) and a denominator (the number of students in a particular baseline population, like enrollees or registrants). This chapter will address the issue of choosing appropriate measures for these numerators and denominators.

[21] It is important to distinguish between institution-level retention (like graduation rates) and course-level retention (like course completion rates). These measures are closely related, but as this thesis focuses on massive open online *courses*, we will primarily examine course-level retention.

traditional courses are relatively well defined across a wide body of literature, a recent wave of research suggests that conventional measures and understandings of retention are not applicable in MOOCs. Open and asynchronous, MOOCs are distinct from brick-and-mortar and even from other online courses in fundamental ways. DeBoer et al. (2013), for instance, argue that conventional interpretations of enrollment, participation, curriculum, and achievement are inadequate when applied to MOOCs. The authors further argue that these variables must be *reconceptualized* so that they have not only updated operational definitions but also updated uses and interpretations.

In this chapter, I reconceptualize retention in MOOCs and develop a new set of supplementary metrics that will allow students, instructors, institutional leaders, and policymakers to more accurately understand the value delivered by these courses. In particular, I will argue that today's MOOCs should be understood and evaluated in terms of *modular* retention[22], and that the conventional measures of course-level retention that dominate discussions of retention in MOOCs at present are more misleading than they are meaningful.

To begin this chapter, I will review foundational theories from the literature on student retention to provide both important context for the debate on retention in MOOCs and a basis for my critique of existing measures of MOOC retention. Next, I will summarize the debate on MOOC retention as a dialectic argument between absolute and relative ways of interpreting certification rates; I

[22] "Modular" retention defines retention with reference to the separate modules that make up a course. Rather than look at retention across an entire course, modular retention looks at the number of students who start and finish the various segments or components that make up the course. I will define and explore this metric in detail in the last section of this chapter.

will describe both the high stakes of this debate and the emergence of a more recent argument suggesting that certification rates are meaningless without reference to student intentions. Third, I will expand the argument that certification rates are misleading by drawing upon both theory and empirical results from HarvardX MOOCs. Finally, I will develop a new set of modular retention metrics and apply them to one HarvardX MOOC, HeroesX, as a case study.

Theories of Student Retention

It is difficult to appreciate the inapplicability of traditional retention metrics to MOOCs without examining the theoretical underpinnings of student retention in higher education more generally. Retention has been an area of research in higher education since the late 19th century (Boston et al. 2011). It has received particular attention after a number of studies in the 1980s revealed that the median dropout rate at postsecondary institutions had remained upwards of 45 percent steadily for more than a hundred years[23] (Bean 1980; Tinto 1982). Alarming findings like these—that nearly half of the entering students at an average postsecondary institution would drop out within four years—have established retention as one of the most important issues facing educational leaders and policymakers. They have likewise spawned a rich literature that attempts to understand the causes of attrition in higher education. While most of these theories and models are derived from analyses of face-to-face learning (i.e., at brick-and-mortar institutions), Simpson (2003) posits that much of this

[23] Tinto (1982) observes that although there were fluctuations in dropout rates during and immediately after World War II when the GI Bill was in effect, the overall trend line is "strikingly constant" for the entirety of this hundred-year period.

literature may be applicable in online settings. I will briefly examine several foundational theories of student retention in an effort to illustrate the variety of mechanisms through which students can drop out of a course or institution. In addition, I will emphasize a common thread in these theories: that defining retention is one of the most critical, difficult, and overlooked aspects of this field of study.

The "longitudinal model of dropout" developed in Tinto (1975) is a foundational theory of student retention. Tinto motivates his theory by observing that "inadequate attention given to definition" has been a major failure in the existing literature, leading to inconsistent and sometimes contradictory research findings. Although "dropout" is implicitly defined across the literature as "leaving college before earning a degree," there are a number of subtleties involved in the act of leaving. For example, Tinto distinguishes dropouts due to academic failure from dropouts due to voluntary withdrawal, as well as permanent dropouts from temporary ones. An adequate theory of student retention, thus, must account for these distinctions, motivating a view of dropout as a (longitudinal) process, not an outcome.

Tinto derives his theoretical model of dropout behavior from a mix of Émile Durkheim's theory of suicide and standard cost-benefit principles from economics. Taking cues from Durkheim, Tinto identifies "integration" as a critical component of retention: just as Durkheim theorizes that suicide results from insufficient integration of an individual into society, Tinto proposes that dropout results from insufficient integration of an individual into an institution of

higher education. Expanding upon this notion, Tinto asserts: "Given individual characteristics, prior experiences, and commitments, [this] model argues that it is the individual's integration into the academic and social systems of the college that most directly relates to his continuance in that college." Integration into academic systems is presented as a function of "grade performance and intellectual development," and integration into social systems is presented as a function of "peer-group interactions and faculty interactions." Though the driving mechanism behind dropout decision-making in this model, integration is conditional upon an individual's fixed characteristics and experiences, and variable levels of commitment. Tinto suggests that an individual's commitment is a function of his or her perceptions about the costs and benefits of attending college, and thus this model incorporates exogenous shocks (such as changes in tuition) that may impact an individual's dropout behavior. In sum, Tinto's longitudinal model of dropout holds that given individual characteristics, experiences, and commitments, students less integrated within the academic and social systems of an institution are more likely to drop out. More bluntly: high integration causes high retention, *ceteris paribus*.

By contrast, Bean (1980) analogizes student attrition in postsecondary institutions with employee turnover in work organizations. As with Tinto, Bean's model is motivated by frustration with careless definitions and inadequate distinctions in the existing literature on student retention; specifically, Bean develops a more explicitly quantifiable model for attrition by drawing on "organizational determinants" from employee turnover theory. In Bean's model,

background variables like socioeconomic status interact with organizational determinants like performance and perceptions of development[24] to influence student satisfaction, which in turn influences dropout. In testing his model empirically, Bean finds that institutional commitment ("the degree of loyalty toward membership in an organization") is the primary variable influencing dropout, which provides some degree of support for Tinto's emphasis on commitments in his model.

While more recent approaches to student retention in online or distance settings are difficult to generalize because they employ broad amalgams of variables in their models[25], one finding is consistent across nearly all studies: retention rates in traditional online settings are significantly lower than those in face-to-face contexts. Dropout rates in online courses are often 10 to 20 percent higher than in traditional classroom environments, prompting critics to label retention as "one of the greatest weaknesses in online education" (Herbert 2006). Given this precedent, we have cause to examine retention rates in MOOCs with great scrutiny.

[24] Bean (1980) defines and empirically tests more than a dozen of these "organizational determinant" variables using multiple regression and path analysis. These variables are chosen to be analogous to those from employee turnover theory; so, for instance, student grade point average (GPA) is substituted for employee pay in Bean's model.

[25] For example, Berge and Huang (2004) group retention-influencing variables into three categories: personal variables, like demographics, abilities, motivations, and commitments; institutional variables, both academic and bureaucratic; and circumstantial variables, encompassing academic and social interactions.

Certification Rates: The MOOC Retention Debate

Even given this precedent of ostensibly high attrition in online education, dropout rates in MOOCs have been nothing short of staggering. Massive dropout rates—usually around 95 percent of registrants—have fueled an intense debate around the value of MOOCs, calling into question whether these courses are legitimate mechanisms for learning, much less whether they can radically transform and improve the landscape of higher education. There are two key sides in this debate: advocates point to the promise of enormous MOOC enrollments and completions when expressed in absolute terms, while critics argue that such "billions served" metrics[26] ignore the overwhelming dropout rates (relative to completions) that are unacceptable at any scale. In this section, I will explain why the certification rate is the most commonly used retention metric in MOOCs, and I will describe the current state of this debate and the research surrounding it in order to motivate a reconceptualization of this debate entirely.

The ideas of student retention and educational value are closely connected. Retention is defined in terms of "completion": typically, degrees and credits represent completions in colleges and traditional courses, while certificates[27] represent completions in MOOCs. Therefore, in discussions of MOOCs, "certification" is generally synonymous with "retention," and the "certification rate" corresponds to the fraction of registrants who complete a course. It is also

[26] This original use of this term is attributed to a February 2013 blog post by educational consultant Phil Hill, available at http://mfeldstein.com/the-most-thorough-description-to-date-of-university-experience-with-mooc/.

[27] In MOOCs offered by HarvardX, these certificates of completion do not count for credit at Harvard or elsewhere; rather, certificates are downloadable, HarvardX-marked documents that students can use as they wish.

important to note that degrees and credits are used as proxies for educational value or output in discussions of productivity and policy in higher education. For example, a recent report by the National Research Council defines productivity in higher education as "the ratio of changes in outputs (credit hours and degrees) to inputs (labor, purchased materials, and capital)" (Sullivan et al. 2012)[28]. Because certificates are most analogous to the credit hours and degrees used to measure educational or instructional output in traditional settings, observers frequently use certificates to represent the value or output of MOOCs. For these reasons, the debate over MOOC retention—that is, the debate over the efficacy of these courses in producing "certified" students—has important implications for the way we understand the value of these courses.

Low retention (quantified by low certification rates) has been the most intense and widely cited criticism of MOOCs as mechanisms for learning since the first such courses launched in 2012. The first MOOC offered on the edX platform, MITx's "6.002x: Circuits and Electronics," had a completion rate of 4.6 percent, as only 7,157 students of approximately 155,000 enrollees satisfactorily completed the course (Breslow et al. 2013). In other words, this course had a dropout rate of 95.4 percent. Because this was edX's highly publicized pilot course and users had to "enroll" just to access the course, it likely received a large number of enrollments from people who were merely curious to see what the MOOC "hype" was about and not interested in actually taking the course. In a

[28] The report also notes that both inputs and outputs should be "quality-adjusted," but concedes that such adjustments are not possible because we cannot measure or quantify quality. Thus, this productivity metric is imperfect but also necessary to motivate decision-making in higher education policy.

post-course interview, edX President and 6.002x instructor Anant Agarwal emphasized the importance of the number of completers when expressed in absolute terms: "It's as many students as might take the [same] course in 40 years at MIT" (Hardesty 2012). Regardless of the dropout rate, this course illustrated that MOOCs can deliver student throughput that dwarfs traditional, brick-and-mortar approaches. And one could imagine that, once the initial media attention died down, only "serious" students would continue to enroll in MOOCs, leading to more reasonable rates of attrition.

But two years later, attrition remains the most persistent issue for MOOCs offered at every school and on every platform. A widely cited[29] study on the first 17 courses offered by the University of Pennsylvania on Coursera found that these courses had an average completion rate of 5 percent, and none greater than 12 percent (Perna et al. 2013). The report also notes that although many thousands of people registered for these courses, student activity (measured by, for example, the number of quizzes attempted by students) dropped off significantly after two weeks, and few students remained active until the course end. These attrition figures are consistent with those from the first waves of HarvardX and MITx courses on edX: on average, 6 percent of course registrants earned certificates, and no course had more than 12 percent of registrants pass (Ho et al. 2014). More than 43,000 certificates of completion were awarded across these sixteen courses, albeit from a baseline of nearly 842,000 registrations.

[29] This study has been featured prominently in both the *New York Times* and the *Wall Street Journal*, for instance.

Because these low certification rates have become a focal point of MOOC coverage in popular media ("Harvard, MIT Online Courses Dropped by 95% of Registrants" headlined one *Bloomberg* article in January 2014), MOOC developers and researchers have called for more nuanced retention metrics, arguing that simple, decontextualized certification rates send misleading messages about what actually happens in these courses. For instance, HarvardX researchers have argued that "'dropping out' is not a breach of expectations but the natural result of an open, free, and asynchronous registration process, where students get just as much as they wish out of a course and registering for a course does not imply a commitment to completing it" (Reich and Ho 2014). Similarly, the founders of Coursera have maintained that discussions of retention in MOOCs are meaningless without reference to student intent (Koller et al. 2013). The current state of the certification rate debate leaves the issue of finding more meaningful measures of value in MOOCs as an open question.

Why Certification Rates are Misleading

In this section, I build upon the growing literature that identifies MOOC certification rates as problematic measures of value. Adopting terminology from DeBoer et al. (2013), I argue that retention must be *reconceptualized*, rather than *reoperationalized*[30] as certification rates, in the context of MOOCs if we are to understand properly the ways students engage with MOOCs and the ways MOOCs deliver educational value. I identify three key reasons that certification

[30] To recapitulate, the framework presented in DeBoer et al. (2013) describes "reoperationalization" as simply updating a metric's operational definition, while "reconceptualization" entails updating intended uses or interpretations as well.

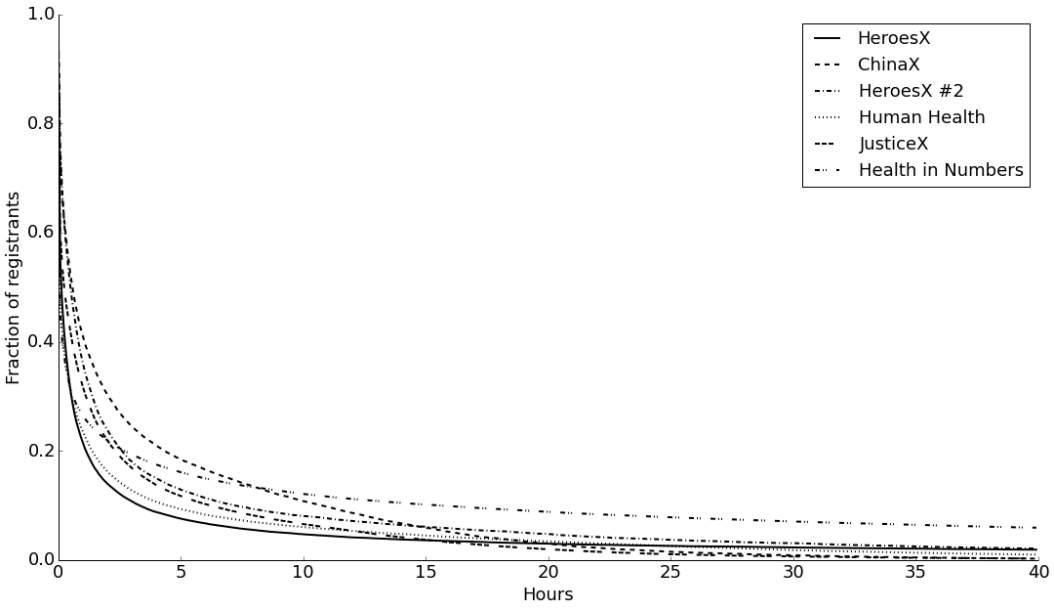
rates are misleading metrics: a) they are highly sensitive to denominator variables like "enrollment" that carry little meaning in MOOCs and must themselves be reconceptualized; b) they are based on certificates that are not key student motivators and have little tangible value for students; and c) they fail to capture the activities, behaviors, and outcomes that many MOOC instructors identify with success.

Denominator Sensitivity and Definition

The first reason certification rates are misleading is that they are highly sensitive to a denominator that is at worst meaningless and at best hard to define. Certification rates are typically operationalized as the fraction of registrants who earn certificates, but it is not clear that "registrants" is a meaningful denominator in the same way that "enrollees" is in a traditional course. On the edX platform, registering involves no more commitment than the press of a button: students make no financial investment (MOOCs are free), there are no consequences for leaving, and students can register at any time (even after the course ends, when it is impossible to earn a certificate). By contrast, enrollment in a traditional course—online or not—typically involves a tuition fee, penalties for leaving, and a deadline for signing up. Analogizing MOOC registrations with traditional course enrollments is tenuous because the requisite levels of commitment are so vastly different. A more appropriate analogy might equate MOOC registration with "shopping" an on-campus course, and indeed several studies (DeBoer et al. 2013; Ho et al. 2014) have suggested that MOOC enrollment be divided into

activity-based subcategories like “browsers” and “auditors” to allow for more accurate inference of student commitment and intent.

Figure 2.1
Minimum Time on Site



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* The concept of “time on site” is borrowed from the web analytics literature; it refers to the total amount of time a user has spent on a website. See Appendix B for a technical description of the methods and assumptions used to calculate time on site from edX tracking logs. This plot is effectively the complementary cumulative distribution function (CCDF) of student time on site; for any value of “hours,” this plot shows the fraction of course registrants who spent at least that many hours in the course.

To illustrate the low level of commitment involved in registering for a MOOC, Figure 2.1 plots the fraction of students who spent at least X hours in a course, for the six HarvardX courses investigated for this study. In each of these courses, most registrants spent at least some time in the course (i.e., opened the site), and between 5 and 12 percent of registrants spent at least 10 hours in the course. The marked drop at the beginning of the plot shows that the majority of

registrants spent very little time in these courses: generally, 25 to 50 percent of registrants spent less than five minutes in a course, and 60 to 80 percent of registrants spent less than one hour in a course. While some might be tempted to conclude that more than two-thirds of HarvardX students drop out in less than an hour, a more plausible interpretation would be that roughly a third of students who shopped HarvardX courses decided to commit more than an hour of their time to their course. If we draw upon the theories of retention discussed earlier, it is difficult to argue that students spending less than an hour in a course would have had any chance at all to "integrate" in the academic or social senses Tinto describes, or that they would have had much "institutional commitment" to begin with in the sense that Bean details. These theories of attrition appear inapplicable because registering for a MOOC does not entail commitment the way enrolling for a traditional course does, and this inapplicability suggests that registrant-based certification rates cannot be interpreted the same ways traditional retention metrics are.

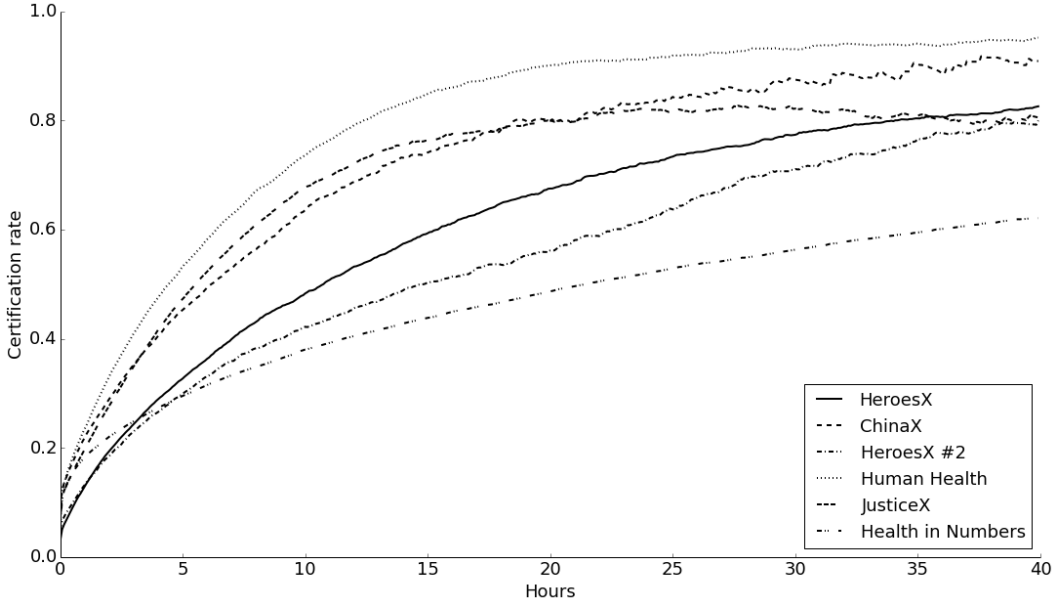
That MOOCs require such low levels of commitment might actually be *adding* to the value of these courses, if students are able to quickly and cheaply determine whether a course is a good match for their abilities and interests. In the language of economics, this is the notion of "option value": students have the option to try MOOCs without committing, and this option is valuable because it allows students to more easily determine which, if any, courses best fit their goals. Put simply, option value reflects the ease of acquiring information about a course. Stange (2012) offers an empirical examination of the option value of conventional

college enrollment. Arguing that postsecondary schooling decisions "involve much uncertainty," Stange finds that option value "accounts for 14 percent of the total value of the opportunity to attend college among all high school graduates and 32 percent for those closer to the enrollment margin." In other words, the option value is substantial and particularly high for students unsure about whether postsecondary education is a worthwhile investment. A MOOC similarly provides option value by allowing students to quickly and freely decide if a course is worth the investment of time and effort. Given that 25 to 50 percent of students invest less than five minutes of their time making what is effectively this decision, the option value of MOOCs could be considerable. Thus, because registrant-based certification rates ignore the concept of option value (all students who leave early are treated as "failures"), they may underestimate the true value of these courses.

However, what makes registrant-based certification rates so misleading is that they mask the incredible sensitivity of MOOC certification rates to their denominators. Figure 2.2, for instance, illustrates how certification rates rise as we look at cohorts spending different amounts of time in a course. While the mean certification rate for these HarvardX courses is 5.7 percent from the pool of all registrants, this rate grows rapidly when we restrict the denominator to students who spent some time in their courses: 18.2 percent of those engaging at least an hour were certified; 39.6 percent of those engaging at least five hours

were certified; 55.6 percent of those engaging at least 10 hours were certified; and 70.4 percent of those engaging at least 20 hours were certified.[31] Of course, the

Figure 2.2
Certification Rate by Minimum Time on Site



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* See Figure 2.1 for a description of time on site. This figure plots certification rates for cohorts spending at least "X" number of hours in a course, across six HarvardX courses.

conclusion here is not that spending more time in a MOOC increases your likelihood of earning a certificate, but rather that certification rates fluctuate wildly across students exhibiting various levels of commitment. If we look at mean certification rates across more activity-driven denominators, we find that 36.9 percent of students who created a forum post were certified; 25.7 percent of students who simply attempted at least one problem were certified; and 70.5

[31] Even when we restrict ourselves to students engaging at least 20 hours, we are analyzing pools of between 665 (ChinaX) and 9207 (Health in Numbers) students, so these percentage figures still reflect a meaningful number of participants.

percent of students who watched[32] more than half of the available videos were certified. Again, these certification rates span a wide range, yet it is not obvious that any one of these denominators is clearer, more interpretable, or "better" than the others.

Altogether, these plots call into question the application of traditional educational definitions to MOOCs. Clearly defining what is meant by terms like "enrollment," "completion," or even "student" or "course," is not a straightforward task because MOOCs operate under different constraints than do traditional courses. As a result, applying conventional definitions, uses, and interpretations of enrollment and retention to MOOCs yields conclusions that are often misleading. MOOCs require a *reconceptualization* of fundamental educational variables like retention so that we can accurately understand the retention rates and the value of these courses.

Certificates Offer Little Value for Students

In addition to being misleading from a definitional standpoint, certification rates are hollow measures of success because this measure's numerator is based upon certificates that offer little value to students. Just as registration for a MOOC is not analogous to enrollment in a traditional course, a MOOC certificate is not analogous to traditional course credit and earning a MOOC certificate is not analogous to passing a traditional course. This may change in the future—already, there are a handful of schools experimenting with offering course credit for select

[32] A student is considered to have "watched" a video if he or she has gone through its entire duration. See Appendix C for an explicit definition of this metric.

MOOC certificates—but in the meantime, student incentive structures in MOOCs are too different from those in traditional courses to allow for meaningful comparisons.

As of early 2014, edX courses offer three types of certificates: honor code certificates, ID verified certificates, and XSeries certificates. Honor code certificates are unverified, free, and downloadable for any student who passes a course. The HarvardX courses in this study only awarded this kind of certificate. By contrast, ID verified certificates are available in some courses for students who pay a fee (typically between $25 and $50) and have their identity verified periodically through their computer webcam. On its website, edX encourages students to consider signing up for ID verified certificates if they plan to use their courses "for job applications, promotions, or school applications." Finally, an XSeries certificate is awarded to students who pass a series of courses in a particular subject, like Aerodynamics; this type of certificate can be thought of as a primitive edX "degree." In each of these cases, however, it is important to note that certificates are both disconnected from course-offering institutions (for example, students who earn honor code certificates in HarvardX courses receive certificates with the logo of HarvardX and not Harvard University) and informal in the sense that they carry no course credit and students are on their own to advertise their achievements.

The extent to which paying for an ID verified certificate promotes retention (i.e., students actually earning these certificates) is an open area of research, but an early analysis by Coursera provides some evidence that this kind

of financial commitment and credentialing may correlate with higher retention. Coursera allows students to sign up for a fee to earn certificates verified via "Signature Track," a biometric technology that identifies students by their keystrokes, in a way analogous to edX's ID verified certificates. The company notes that in the first Signature Track class, "Nutrition for Health Promotion and Disease Prevention" offered by the University of California, San Francisco, 74 percent of Signature Track students passed the course, versus 9 percent of non-Signature Track students (Koller et al. 2013). It is not clear whether this difference is externally valid across other courses and disciplines, nor whether difference arises from the promise of earning a verifiable certificate, the cognitive dissonance of wasting money, bias from the selection of more committed students, some combination of these factors, or other factors altogether. Randomized, controlled experiments are needed to draw any such conclusions. However, this example does provide some degree of validation for the intuition that free certificates, like edX's honor code certificates, are not comparable to certificates, credits, and degrees that cost money.

The effect on retention of offering for-credit MOOCs is likewise an open area of research. Although critics have argued that the early results from three pilot courses offered at San Jose State University through a partnership with Udacity show that even for-credit MOOCs have low certification rates, it is unclear how generalizable these results actually are. Across the three introductory and remedial math and statistics courses, the completion rates for San Jose State

students ranged from 29 to 51 percent (Kolowich 2013).[33] Nonetheless, these figures ought to be generalized with caution because there were only 98 matriculated students in the study and because the study "specifically targeted at-risk populations," including students who had failed the face-to-face versions of these courses before (Collins 2013). As this is the only documented study of using MOOCs as such in for-credit settings, it remains to be seen whether retention in these settings can be used as a viable success metric for evaluating the technology.

For more direct illustrations of student intentions and perceptions of certificates, we can look to early findings from student surveys offered in the most recent semester of HarvardX courses. Pre-course surveys for ChinaX, for instance, show that only 43.6 percent of respondents considered earning a certificate "important" in their decision to register, whereas 76.5 percent considered "learning from the best professors and schools" important, 74.4 percent considered "engaging in lifelong learning" important, and 72.1 percent considered "accessing learning opportunities otherwise unavailable to me" important. In other words, survey respondents considered learning opportunities much more important than certificates. While these responses should not be generalized across courses (particularly to more vocational topics like computer science), they further validate the argument that certificates are not necessarily indicative of student "success" in MOOCs.

[33] These figures were the subjects of extensive media coverage—in part due to backlash from San Jose State faculty over the use of JusticeX (a HarvardX introductory course on moral and political philosophy) in on-campus classes—prompting headlines like, "The Online Education Revolution Drifts Off Course" (*NPR* 2013) and, with reference to Udacity founder Sebastian Thrun, "The King of MOOCs Abdicates the Throne" (*Slate* 2013).

In short, certificates are often not meaningful indicators of "good outcomes" in MOOCs because certificates—particularly the free honor code certificates that are most common—do not incentivize and motivate students in the same ways that traditional course credits do.

Certificates Fail to Capture What Instructors Value

Finally, certificates are often not meaningful success metrics for the instructors that teach these courses, particularly those in the humanities. For example, according to interviews in Reich et al. (2014) with the course team for JusticeX, the goals of the course were "more focused on sharing their [the professor and course staff's] perspectives and sparking student interest and reflection than in evaluating, sorting, and certifying students." Consequently, the success of this course should be measured by the extent to which it was able to share perspectives and spark student interest and reflection, rather than by the extent to which it was able to certify students.

Another HarvardX humanities course, HeroesX, further downplayed the significance of certificates by rebranding itself as a "project" instead of a "course." In the first week of the Spring 2013 version, Professors Greg Nagy and Lenny Muellner posted a message on the course page clarified that all students "are free to participate as an 'explorer' by simply enjoying some of the content and discussions. That way, you are not obligated to do any of the exercises, and you are simply coming along for the ride. That way of participating is just as legitimate and honorable as the 'certificate' option." Again, the emphasis of this

course was on engagement with the content instead of certification. Citing low certification rates, therefore, will not provide an accurate depiction of how successful this course was in achieving its objectives.

Alternative Measures of Value

So far this chapter has taken a somewhat nihilist approach toward the analysis of MOOCs, arguing that it is difficult to compare these courses with traditional ones or even other MOOCs because our metrics for comparison—like enrollment and retention—are often misleading and in some cases meaningless. Put another way, it is difficult to evaluate the educational efficacy and societal value that MOOCs offer because conventional frameworks and reference points do not apply. In this section, I propose an imperfect but improved set of retention metrics for understanding the value offered by these courses. Rather than being based on tenuous definitions of enrollment, certification, and completion, these metrics are based on modular engagement with course material, and they allow for a more complete understanding of the value MOOCs offer students and society. To illustrate these proposed metrics, I will draw on the Spring 2013 offering of HeroesX as a case study.

Ideally, we might measure the societal value of MOOCs—and any other type of course—by the amount of student learning. In discussions of productivity in higher education, measuring student learning is tantamount to measuring the quality of an education. In a major paper by the National Research Council defining a rubric for evaluating productivity in higher education, Sullivan et al.

(2012) stress that the lack of an agreed upon measure of educational quality is the chief impediment to evaluating productivity across institutions and policies. The authors argue that degrees and credit hours are not complete measures of what higher education produces, and that "ignoring measures of learning outcomes or student engagement (while, perhaps, emphasizing graduation rates) may result in misleading conclusions about institutional performance and ill-informed policy prescriptions." Despite the importance of evaluating educational quality, we continue to lack accepted standards for measuring it. At present, there are no easy ways to evaluate learning outcomes in MOOCs, in large part due to the lack of diagnostic tests to establish student knowledge baselines. And as we have seen, certificates are poor measures of learning because students are not obligated to pursue them and because certificates fail to capture more granular learning by students who only interact with parts of the course. A more meaningful proxy for the learning, quality, and value of a MOOC, then, might be derived from engagement.

In HeroesX, students were encouraged to enjoy "some of the content and discussions." Content and discussions generally encapsulate the largest of avenues for student engagement in HarvardX MOOCs and are thus reasonable bases for evaluatory metrics. Content is primarily delivered through videos[34], while discussions typically take place in the online forums. While it is difficult to

[34] Although HeroesX has substantial reading content as well, estimating the time students spend reading is far more difficult than estimating the time students spend watching videos. Students likely read at different speeds, it is difficult to tell when and where a student starts or stops reading, and readings are often presented on pages with other kinds of content (such as quiz questions). Ideally, however, we would want to be able to quantify retention in reading content just as we can in video content.

measure the quality of student interactions with content and other students, we can use videos and forums as bases for measures of student retention that more accurately reflect the aims and value of the course. Importantly, the HeroesX staff's phrasing "*some* [emphasis added] of the content and discussions" was deliberate, reflecting that students can engage with the course legitimately without doing so exhaustively. This approach lends itself to a more modular view of engagement, completion, and, thus, retention. Rather than view the course as a single, indivisible unit, we should view the course as a collection of smaller units, each of which may be legitimately and separately engaged. Thus, assuming starting a video indicates a student's intent to engage with the video's content, we can ask: a) What fraction of students who begin watching a video finish it; and b) what fraction of these "starters" discuss the video content in the forums? I will refer to these ideas as "video retention" and "discussion retention."

In operationalizing these two metrics, I will borrow a concept from the literature on online video streaming: viewer abandonment. Viewer abandonment refers to the fraction of viewers who start but do not finish a video. This metric is one of the core variables tracked by video streaming juggernauts like YouTube (upon which edX videos are based) and has become a central measure in video analytics more broadly as streaming media has grown to account for more than half of all Internet traffic today (Sandvine 2013). Viewer abandonment is a particularly important metric because most viewers do not finish videos; a commonly cited study by Visible Measures, for instance, found that across 40 million unique short-form (i.e., 5 or fewer minutes in duration) videos, roughly a

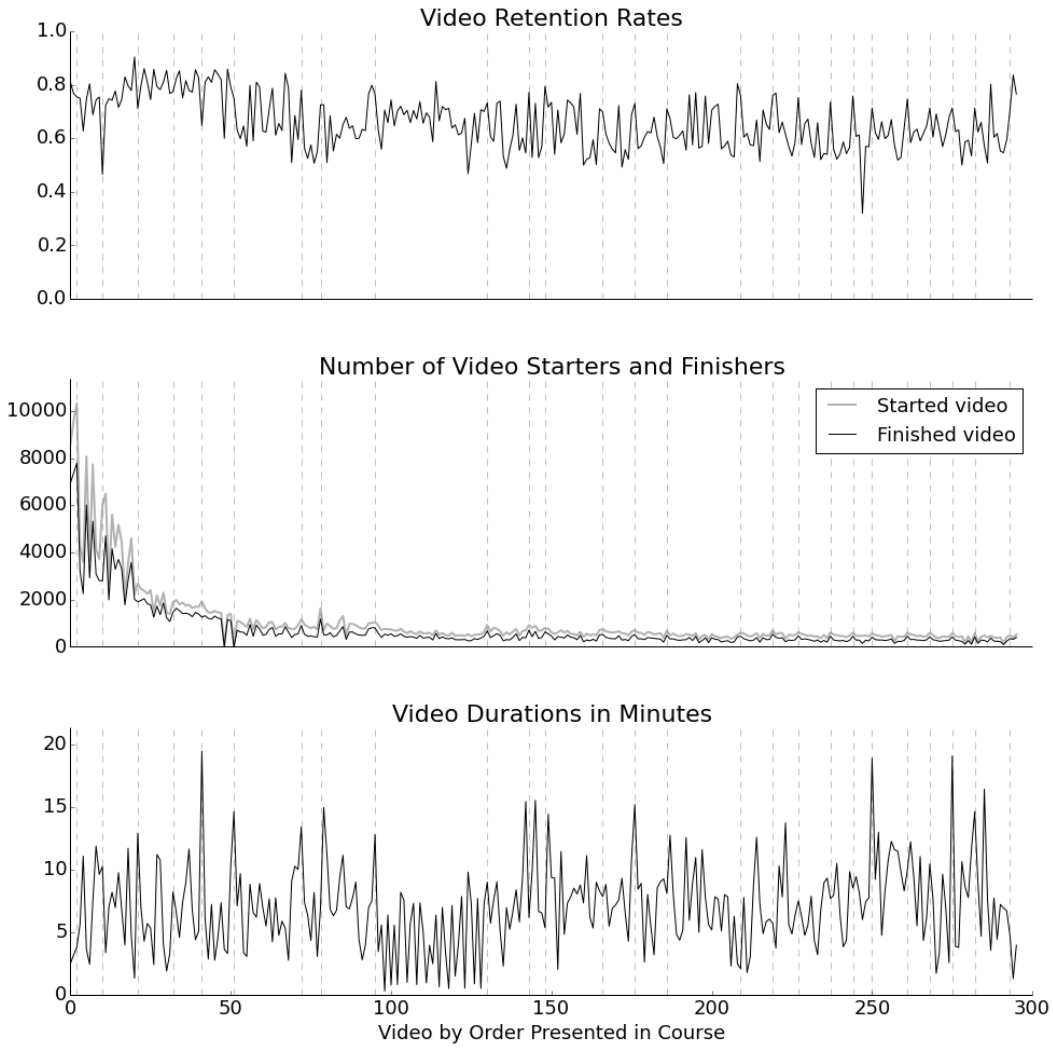
third of viewers "abandon" within 30 seconds and more than half of viewers stop watching within 90 seconds (Visible Measures 2010). Although these figures are typically analyzed in the domain of online advertising, we can apply the same principles to the videos that drive most content delivery in MOOCs, and we can extend these ideas to encompass other engagement-based outcomes like posting or commenting in the discussion forums.

To develop these metrics for HeroesX, we need to understand the course's modular, chapter-based structure. There are 296 videos in HeroesX across 24 "chapters" of content (i.e., units, which in HeroesX are called "Hours" and correspond to the 24 hours of direct contact time Professor Nagy spends with students in the on-campus version of Heroes at Harvard University), two introductory chapters, and one concluding chapter. On average, there are 77 minutes of content across 11 videos per chapter, yet both chapters and videos vary substantially in duration and division. Videos range from just 17 seconds (a short passage reading) to nearly 20 minutes, while chapters range from 6 minutes to more than 2.5 hours of content spread across as few as 2 or as many as 35 different videos. Each chapter beginning with Hour 5 also has a dedicated section in the course discussion forums where students are encouraged to address discussion questions. Given this structure, we can measure a) the proportion of video starters who finish videos, and how this proportion changes across chapters, and b) the proportion of video starters who either post or comment (i.e., discuss) in the chapter's section in the forums.

Figure 2.3 offers a visual representation of the first of these metrics as applied to HeroesX. There are three plots, and they share the same horizontal axis of videos arranged in the order they are presented in the course. The first video of the course is at the far left, and the last video is at the far right. Dashed vertical lines delineate chapters; these lines are not evenly spaced because some chapters have more videos than others. The top plot shows for each video the fraction of starters who finish—what we might call "video retention," effectively the inverse of viewer abandonment. What is striking about this plot is that video retention rates remain fairly constant and fairly high (hovering around 66 percent) across all chapters of the course. It is not surprising that there is variation in retention from video to video—different videos offer different kinds of content—but it is noteworthy that the video retention rates in the early chapters of the course are roughly the same as those in the closing chapters.

To contextualize the relative figures in the video retention plot, the middle plot of Figure 2.3 shows the absolute number of students who started and finished each video, and the bottom plot shows the absolute duration of each video. As expected, the number of students who view videos drops quickly after the first few chapters of the course, characteristic of the high "dropout" rates we discussed in previous sections. Most students stop engaging after the beginning of the course, but as the HeroesX course staff has stressed, this is a perfectly legitimate way of "taking" the course. The number of students viewing videos levels off between 500 and 1000 for the remainder of the course. Again, both at the beginning of the course when some 10,000 students start watching videos and at

Figure 2.3
Video Retention in HeroesX



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* Plots share the same horizontal axis, which corresponds to HeroesX videos in the order they are presented in the course. That is, video 0 is the first video in the first chapter of the course, while video 296 is the last video in the last chapter of the course. Dashed vertical lines delineate chapters, again by the order they appear in the course (for this iteration of HeroesX, the videos before the leftmost dashed vertical line belong to an introductory chapter "previewing" the course, and videos after the rightmost dashed vertical line belong to the "Afterword" chapter wrapping up the course). The top plot is calculated by dividing the number of students who finish each video by the number of students who start each video. The middle plot displays the absolute number of video starters and finishers for each video. The bottom plot shows the duration of each video in minutes. See Appendix C for a technical explanation of the methods and assumptions involved in using edX log data to calculate the number of students who finish a video.

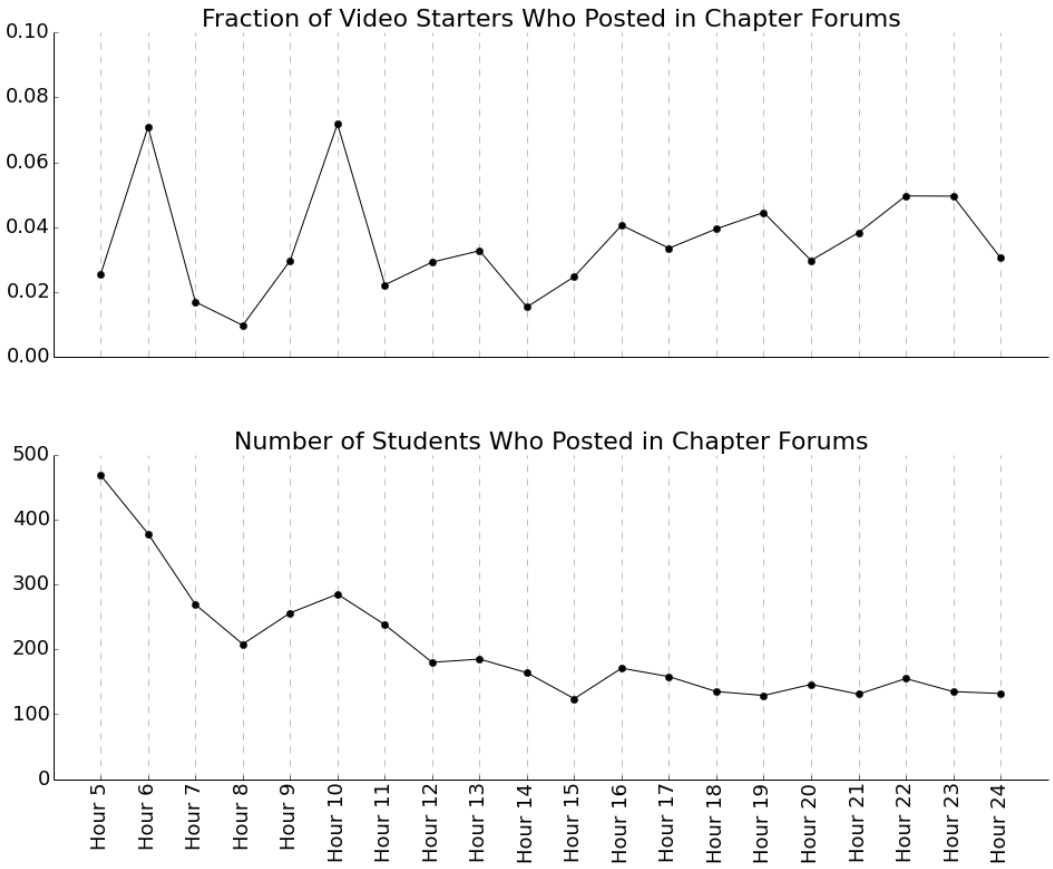
the end of the course when closer to 500 students start watching videos, the video retention rates in the top plot remain similar. Likewise, the bottom plot illustrates that across a wide variation in video durations and chapter patterns[35], video retention rates are roughly constant.

Overall, modular video retention paints a fairly positive picture of HeroesX. In total, 18,842 students began watching at least one video, with an average of 85.6 minutes of video watched by students throughout the course. Cumulatively, students watched 26,875 hours of video. Consistently high retention rates across videos suggest that the quality of this content was high as well, and that a large number of students engaging with HeroesX were interested in and benefited from the course videos.

Switching to discussion retention, Figure 2.4 plots both the fraction of video starters in each chapter who post in the corresponding chapter forum, and the absolute number of students who posted in each chapter forum. As with video, the number of students engaging with the forums declines and stabilizes from early to later chapters. On average, roughly 3 percent of students who start watching a video in a chapter—we assume demonstrating an intent to engage with the chapter's content—go on to post in the corresponding chapter forum. While this percentage generally corresponds to a few hundred students, it is somewhat low in light of the emphasis on discussion in the course goals outlined by the HeroesX staff. This is not to say that the hundreds of students engaging in the forums did not have high quality discourse—in fact, the quality of forum posts

[35] While most chapters have a handful of medium to long videos, Hour 8 featured a series of shorter passage-reading clips. This structure is evident in the bottom plot of Figure 3, where Hour 8 includes the videos between roughly 100 and 130.

Figure 2.4
Discussion Retention in HeroesX



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* Plots share the same horizontal axis, corresponding to each chapter or "Hour" in HeroesX. Beginning with Hour 5, each chapter in HeroesX has a) its own section in the course discussion forums, and b) its own page encouraging students to discuss question prompts. The top plot shows for each chapter the fraction of students who started watching video in the chapter that also posted in the chapter's section of the discussion forum. The bottom plot shows the total number of students who posted in each chapter's section of the discussion forum. In this plot, "posting" in the forums can be done either by creating a new discussion thread or by replying to an existing one.

was one of the great successes identified by the course staff—but rather to illustrate that the vast majority of students who demonstrated intent to engage with a chapter do not discuss it. Because most students engaged with videos and not the discussion forums, it would not be unreasonable to assert that the

predominant mode of engagement with HeroesX content was analogous to watching a series of educational videos like documentaries or TED Talks.

Stepping back, I would like to anticipate a key objection to the video and discussion retention metrics I have proposed above. The most readily apparent criticism of my modular, chapter-based approach to retention in HeroesX (which, I argue, can be extended to MOOCs more generally) is that it ignores retention from chapter to chapter. In using a chapter instead of a course as our unit of analysis, we treat the course as more disjointed than it actually is. Particularly in courses with cumulative content, where the content in later chapters depends on content in earlier chapters, it seems important to consider retention at the course level.

While course level retention is a key measure in traditional courses where intentions, outcomes, and trajectories are well defined, I would argue that this measure can be less meaningful in MOOCs where 1) student intentions are highly variable and generally oriented more toward learning than toward certification, 2) the outcome of "completion" is tenuous to define because students are encouraged to engage with however much content they want, and 3) there is no single trajectory through open and asynchronous courses where students can start, quit, and skip as they please to selectively engage with content relevant to their interests. For MOOCs, therefore, course level retention is often a less meaningful indicator of student success or derived value than modular retention.

Nonetheless, the analogy between a MOOC and a TED Talk offers a perspective for roughly synthesizing these modular retention metrics with course-

level, certification-based ones. If we view the educational experience of a MOOC as somewhere between watching a single TED Talk and taking a rigorous on-campus course, we can ask, how many MOOC students had significant educational experiences? Let us assume that all students who earned certificates did—1,400 students in HeroesX. Moreover, let us assume students who did not earn certificates but either watched more than two hours of video or posted or replied at least five times on the discussion forums likewise had significant educational experiences. Combining these sub-populations, we estimate that 2,881 students—more than twice as many as earned certificates—had significant educational experiences in HeroesX. For the two other courses in this study with complete video and forum data, ChinaX and HeroesX #2, these same calculations yield 3,627 and 1,457 students with significant educational experiences, versus baselines of 2,021 and 731 certificate earners. While these distinctions are arbitrary, they help quantify the experiences certification counts miss. These numbers demonstrate that modular, video- and discussion-based views of retention can supplement course-level, certification-based ones and substantially impact our interpretation of the value delivered by these courses.

Summary

Through the lens of retention, this chapter has challenged conventional interpretations of value and success in MOOCs. These interpretations have important ramifications for institutional leaders and policymakers because the decision to invest in this new technology is expensive and controversial. These

interpretations also have important ramifications for instructors and faculty who are designing or plan to design MOOCs because many concepts and strategies from traditional courses do not apply. Extending the reconceptualization framework presented in DeBoer et al. (2013), I argue that retention, success, and value in MOOCs cannot be understood through conventional, course-level metrics. The simple reoperationalization of pass rates in traditional courses as certification rates in MOOCs—the approach currently adopted in the nascent MOOC literature and more prominently in popular media discussions—results in a misleading metric based on certificates that mean little to both students and instructors. To understand the societal contribution MOOCs make, we need to reconceptualize retention to better capture what MOOCs actually offer.

To that end, I have developed a series of more meaningful retention metrics based on a more modular view of MOOCs. These metrics are based on modular engagement (like video viewing and forum participation), rather than certification and registration, offering more accurate measures of successful outcomes and student intent. In applying these metrics to the Spring 2013 iteration of HeroesX, I find that video retention is consistently high throughout the course, while discussion retention is much lower. Together, these metrics suggest that many students derive substantial value from videos throughout the course, and a much smaller core of students derive value from discussions. More generally, however, the most important takeaway is that we have the tools to craft significantly more meaningful measures of success, value, and retention to better inform instructors, policymakers, and students alike. Instead of discussing

MOOCs in terms of facile certification-based retention statistics, we should employ new metrics like modular retention that more honestly portray these courses and their contributions to society.

Chapter Three
Asynchronicity, Interactivity, and the Implications of Openness

MOOCs are defined by openness. Any person in any place at nearly any time may register, generally free of charge. For those who see MOOCs as mechanisms for the "democratization" of education, this lack of restriction is one of the technology's greatest selling points. But such open access does not come free. Because students can engage when they want, where they want, and as frequently or infrequently as they want, there is a high degree of asynchronicity in MOOCs. Asynchronicity, thus, is the degree to which students are "out of sync" with each other, engaging with a course at different times and in different places. Asynchronicity is important because it is a major determinant of the types and degrees of interactivity possible in a course. Interactivity—between students and content, students and instructors, and students and other students—is important because it shapes the educational experience. Differing levels and types of interactivity create fundamentally different student experiences, and as a result, we can say that interactivity defines what it means to be a student.

The ways students interact with MOOCs are distinct from the ways students interact with brick-and-mortar or even traditional online courses: beyond the digital medium, students "meet" in different places and proceed at different paces. Consequently, conventional conceptions of "students" are inadequate when applied to MOOCs. The MOOC student, in the language of DeBoer et al. (2013), must be reconceptualized to account for the distinct and diverse new modes of interaction possible in these courses. In this chapter, I will argue that there is no singular, ideal-typical MOOC student; rather, there is a multiplicity of different paths through a course that is inadequately covered in both traditional and current categorizations of students. As with retention last chapter, we must think beyond conventional metrics and ideas if we are to understand MOOC students properly.

We begin by discussing the theoretical confluence of asynchronicity, interactivity, and openness in MOOCs, and we will explore why these ideas are important for our understanding of what it means to be a MOOC student. We will then review existing approaches to defining such a student and attempt to advance our reconceptualization of the MOOC student through an empirical examination of the levels of asynchronicity and interactivity in early HarvardX MOOCs. Finally, we will discuss the implications of this reconceptualization for MOOC researchers, designers, and instructors. While these analyses are largely starting points for future research, they reveal valuable concerns and opportunities for those who engage with these courses.

Theoretical Tensions

Theories of asynchronicity, interactivity, and openness are few and far between in the distance education literature, and formal analyses are especially rare with respect to MOOCs. In this section, I will connect these three concepts as they relate to MOOCs, traditional distance education, and brick-and-mortar classrooms. Then, I will review recent theories of interaction and asynchronicity in distance education to explain why these ideas are important to our understanding of the educational experience. These theories will help clarify how past interpretations of asynchronicity and interactivity are both applicable and inapplicable to MOOCs.

Openness is a distinctive characteristic of MOOCs[36]. Unlike traditional distance or brick-and-mortar courses, MOOCs allow students to join, participate, and leave with virtually no restrictions. Virtually anyone with access to the internet and a computer—regardless of background, location, and qualifications—can join. Students can start taking a MOOC at virtually any time, and they can often begin at any location within the course (as an extreme example, a student could conceivably start late and take a course backwards, working through lessons in reverse order). Students are free to skip any or as many sections they wish, and they may quit at any point without penalty. While some MOOCs place deadlines on their assignments, others, like HeroesX, do not. As we have seen, these aspects of openness have important implications for our conceptualization of retention

[36] MOOCs are, of course, offered in a variety of different formats. Structural features (such as whether students are allowed to enroll throughout the course, or whether assignments have deadlines) vary from course to course and from platform to platform. For concreteness, I will restrict my analysis in this section to HarvardX MOOCs, which are roughly representative of the courses offered on the edX platform.

and success in MOOCs. Likewise, openness profoundly affects our understanding of how students can interact and engage with these courses.

Openness allows for asynchronicity. Because MOOCs are less rigidly structured than traditional distance or brick-and-mortar courses, students have a broader variety of ways to participate. Given this lack of restriction, it is reasonable to expect students to engage with a MOOC at different times and in different locations in the course. We can define, thus, two views of asynchronicity. On the one hand, students can begin and be active at different times; we can call this "temporal asynchronicity." On the other hand, students can begin and be active at different locations structurally within the course; we can call this "spatial asynchronicity." In MOOCs, openness enables both temporal and spatial asynchronicity.

In traditional online education and distance learning more broadly, asynchronicity often is present to a lesser degree. These courses are typically more restrictive than MOOCs, particularly with respect to spatial asynchronicity: while students may engage with a course at different times, they are usually required to keep pace with weekly schedules and are not able to skip to other sections of the course with flexibility. In brick-and-mortar courses, conversely, asynchronicity is largely irrelevant because students meet and, in general, progress together—in contrast to MOOCs, such courses are "synchronous."

While openness allows for asynchronicity, asynchronicity both enables and precludes certain types of interactions. Highly asynchronous courses like MOOCs, for example, may allow students from disparate locations to engage in

dialogue, while they may also prevent real-time, face-to-face debate. In this way, openness and asynchronicity are closely related to the types and degrees of interactivity possible in a course.

Having drawn these theoretical connections between openness, asynchronicity, and interactivity, we can examine the frameworks of interaction that distance education theorists have constructed in the past. The most foundational of these frameworks is Michael G. Moore's "Theory of Transactional Distance." This theory derives from John Dewey's famous characterization of education as a "transaction taking place between an individual and what, at the time, constitutes his environment" (Dewey 1938). As Anderson (2003) points out, this conceptualization "not only fits neatly with the complex shifting of time and place that defines distance education but also emphasizes the importance of interaction with the various human and nonhuman actors that constitute the environment." For Moore, however, transactional *distance* represents the "communications gap" that arises from the physical separation of teacher and learner in distance education (Moore and Kearsley 1996). According to Moore, this transactional distance is mediated by dialog and course structure; under this framework, larger transactional distances place greater responsibility on students to guide their own educational experiences independently.

Building upon this foundation, Moore (1989) clarifies that there are three types of interaction that influence transactional distance: learner-content interaction, learner-instructor interaction, and learner-learner interaction. While the first two types of interactions had been characteristic of distance learning as

far back as the original correspondence courses, learner-learner interaction was a relatively new addition that resonated with critics of distance education's tendency toward self-directed learning. For instance, Garrison (2003) argues that "communities of inquiry" are essential to "higher-order learning," and that "even the innermost learning activities occur in a social context mediated by communicative action." Where theories of distance education had traditionally conceived of students as deeply independent, more recent theories have thus pushed back in favor of more collaborative learning.

With specific regard to asynchronicity and the types of interaction it affects, Garrison et al. (2003) presents a binary debate: "Advocates of synchronous communication argue that real-time learning environments are critical for coalescing the class experience, providing high levels of socialization, and supporting critical feedback between teachers and students." Advocates of asynchronous learning, on the other hand, "point to the greater independence from temporal and geographic barriers and the opportunity for more reflective participation." Of course, no single style—synchronous or asynchronous—is ideal for all students, and courses are not necessarily one or the other. But there are theoretical tradeoffs imposed by these styles, and these tradeoffs define what it means to be a student.

Defining the MOOC Student

There is no ideal-typical MOOC student. Unlike less open brick-and-mortar or even traditional online courses, MOOCs allow students to pursue many

different paths of engagement. As a result, it is difficult to describe or identify exemplars of "normal" student activity in MOOCs. Thus, there is a central tension both in this section and in the literature more broadly: we must aggregate findings to generalize results and categories, but at the same time we must not over-generalize and fail to account for the many different types of behaviors that MOOCs permit. To borrow from the lexicon of statistics, in discussing MOOCs we must be wary of singular "point estimates" and instead favor rich "distributions" when describing student activity.

With these caveats in mind, this section attempts to characterize at least some of the modes by which students interact with HarvardX MOOCs. First, I will review the existing approaches researchers have taken to categorize and define MOOC "students." Second, I will begin to formulate a novel, trajectory-based approach, arguing that existing categorizations do not sufficiently account for the asynchronicity present in these courses. And third, I will explore the extent to which this asynchronicity imposes limits on interactivity in MOOCs. These explorations will reinforce the notion that conventional characterizations of MOOC students may be too simplistic, and they will also contribute empirical baselines by which students, instructors, institutions, and policymakers can better understand the interactions possible in existing MOOCs.

Existing Approaches to Defining Students

As was discussed at length in the previous chapter, treating all MOOC registrants as "students" can generate misleading conclusions; as a result, MOOC

researchers have begun to distinguish between different categories of students in their analyses. At present, researchers generally categorize students *ex post* by outcomes, under the assumptions that a) student outcomes are reasonable proxies for student intent, and b) student intent is the most meaningful way to categorize students and account for MOOC openness. For example, Banerjee and Duflo (2013) hierarchically categorize students as "registrants," "starters" (students who ever viewed any page), and "active users" (students who attempted any assignments). Obviously, these categories overlap: all active users are necessarily starters, and all starters are necessarily registrants. Presumably, active users have demonstrated greater intent than starters to engage with the course, so researchers should treat these groups of students differently. Alternatively, DeBoer et al. (2013) suggest simply categorizing students as "completers" (certificate earners), "shoppers" (non-completers who are active five or fewer days), "dabblers" (non-completers who are active six to fifteen days), and "auditors" (non-completers who are active sixteen or more days). The more recent HarvardX Working Papers define "four mutually exclusive and exhaustive categories of course registrants":

> *Only Registered*: Registrants who never access the courseware.
> *Only Viewed*: Non-certified registrants who access the courseware, accessing less than half of the available chapters.
> *Only Explored*: Non-certified registrants who access more than half of the available chapters in the courseware.
> *Certified*: Registrants who earn a certificate in the course. (Ho et al. 2014)

Though constructive, these categorization schemes are arbitrary and complicated. Particularly on the margin, it is not clear that, for instance, a "shopper" who is active for five days is materially different from a "dabbler" who is active for six.

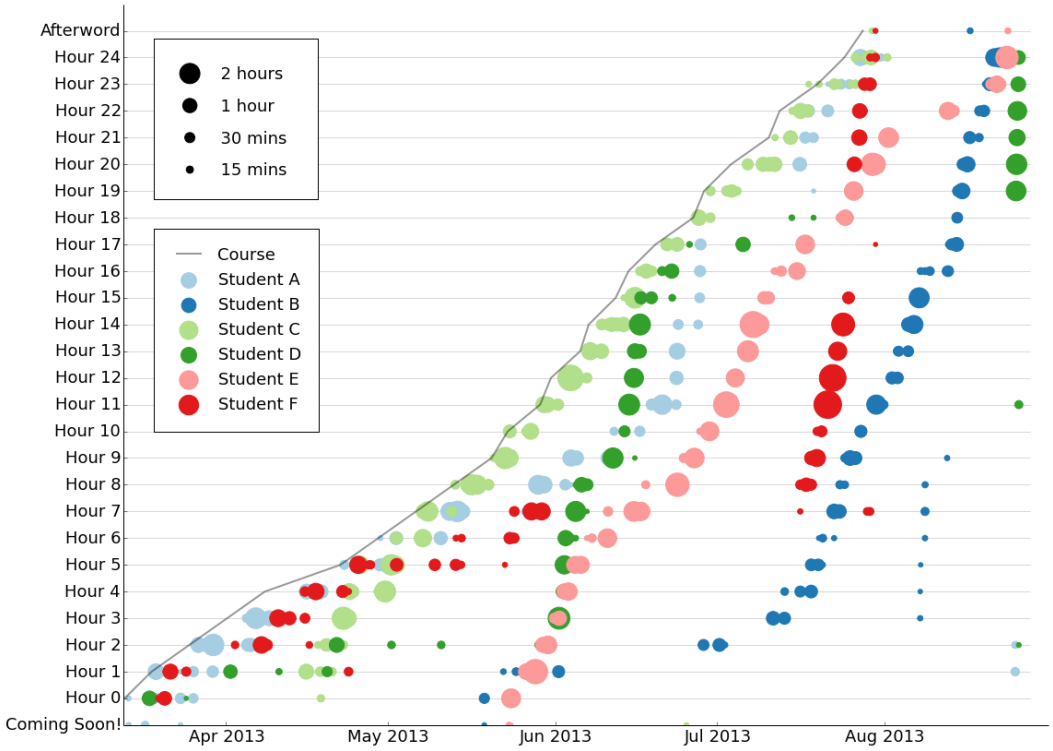
More importantly, however, the lack of consensus with respect to these categorizations suggests that accounting for openness is a critical and unresolved issue in MOOC research.

Student Trajectories and Spatial Asynchronicity

I argue that the above, outcome-centric attempts at categorizing MOOC students have ignored the important and varied paths students take through these courses. Bluntly stated, focusing only on where students ended up ignores how students got there. The notion of "how students got there" obtains heightened importance in studies of MOOCs because these courses are so open, unrestricted, and asynchronous. The literature is missing a categorization of students that accounts for the asynchronicity inherent in these courses, and this absence reflects a failure to adequately reconceptualize what it means to be a student in a MOOC.

To advance our reconceptualization of the MOOC student, I will introduce the idea of a student's "trajectory," or path, through a course. A student trajectory provides a structural view of learner-content interaction, visualizing the pace and regularity of a student's experience with the course. Figure 3.1 plots these trajectories for six students, labeled 'A' through 'F,' from HeroesX. The horizontal axis depicts absolute time, the vertical axis depicts course chapters, and dots represent sessions, where larger dots correspond to longer sessions. The solid line running from the lower left to the upper right indicates when each chapter was made available to students.

Figure 3.1
Sample HeroesX Student Trajectories



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* This figure plots the chapter sessions for six of the 559 students in HeroesX who touched every chapter. These students were not selected randomly; instead, they were chosen to illustrate the variety of ways that students—even those who go through the course exhaustively—progress. The horizontal axis corresponds to absolute time, the vertical axis corresponds to chapters, and dots represent sessions, where larger dots indicate longer sessions. Each color corresponds to a different student, and the solid gray line indicates when each chapter, or "Hour," was first made available to students. Sessions lasting under 5 minutes have been dropped for clarity.

I have selected these six particular trajectories to illustrate the wide diversity of student paths through this course. Each of these students not only earned a certificate in HeroesX but also went through (or "attended," if we apply the term loosely) every chapter of the course; thus, this sample offers a conservative view of asynchronicity in this MOOC in that it ignores the vast majority of students who partially complete the course. This figure, in effect,

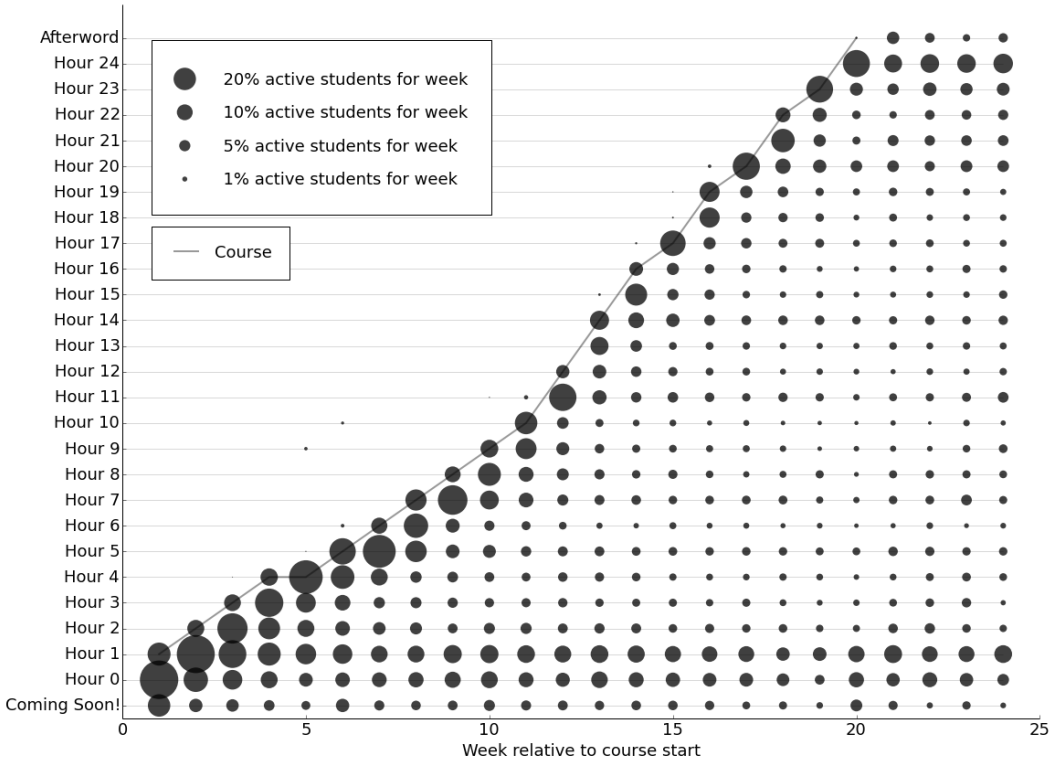
looks only at students whom, based on outcomes, we might categorize as "completionists."

Yet even though we have selected students with similar outcomes, Figure 3.1 demonstrates that these students have taken very different paths through the course. Students A and C are perhaps most similar to students taking synchronous, brick-and-mortar courses in that they engage with the chapters regularly and roughly keep pace with the course from start to finish. Student B, on the other hand, does not even look at the course until two months after it launches; even then, this student doesn't begin engaging substantively until a month later, and then he or she progresses at an accelerated pace through the remainder of the course. Student D looks at the course when it launches, moves through a large amount of content quickly to catch up with the course a couple months later, and then breaks and engages with the last handful of chapters all at once just before the course closes. Student E attends with more regular sessions but does not start until months after the course launches and never quite catches up to the course itself. Finally, Student F keeps pace at the beginning of the course, drops off for a month and a half, and then quickly moves through the remaining chapters while spending almost no time on several of them. In short, these student trajectories vary immensely in their starting points, regularity, and variable pace despite their similar endpoints. The variety in these trajectories reflects a high degree of spatial asynchronicity and suggests that these students had very different experiences in taking this MOOC.

The sample of students in Figure 3.1 demonstrates that spatial asynchronicity exists in HeroesX; this finding, however, begs the question of how much asynchronicity there actually is. While this notion is difficult to quantify succinctly, Figure 3.2 attempts to provide a visual aggregation of the spatial asynchronicity in HeroesX. As before, the vertical axis corresponds to chapters in the course, and the solid line indicates when each chapter was made available to students. However, rather than plotting continuous time, this figure bins time into weekly intervals relative to the course start. Each column, thus, represents one week of the course. Dots indicate the fraction of students in a given week that spent most of their time in a given chapter; for instance, the dots in the first (leftmost) week of the course show that the majority of students in the first week of the course spent most of their time in "Hour 0."

At first glance, Figure 3.2 seems to suggest a fairly high degree of synchronicity with the course: almost every week, the most visited chapter is the most current one available. The moderately sized dots along the bottom of the plot can be attributed to the roughly constant influx of new registrants who "shop" the first chapter or two and then leave. So, at least in aggregate, students appear to be progressing with the course. However, this synchronicity is far less pronounced than it appears, particularly in the later weeks of the course. Although there is a distinct mass of students at pace with the course each week, this mass rarely exceeds 25 to 30 percent. In Week 19, for example, 28 percent of students spent most of their time in Hour 23, the most current chapter available; 13 percent of students spent most of their time in the beginning three chapters; and more than

Figure 3.2
Where HeroesX Spent Most Time, per Week



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* This scatterplot shows the weekly distributions of student locations in HeroesX. The horizontal axis corresponds to time, measured in weeks relative to the course start (March 13, 2013); the vertical axis corresponds to the chapters that form the course's structure; and the dots represent fractions of active students per week (i.e., column). Large dots indicate that a large fraction of students active that week spend the majority of their time in that chapter. The moderately sized dots along the bottom of the plot reflect fairly constant flows of newcomers who join the course, look at the beginning chapters, and leave. Students are considered "active" if they spend at least 5 minutes engaging with the course in a given week.

58 percent of students spent most of their time in other chapters. The fact that nearly three-quarters of students active in a given week focused on past chapters illustrates that most students were not in sync with the course; likewise, the fact that no more than a quarter of students active in a typical week focused on the same chapter shows that most students were not in sync with each other, either. Together, these results reinforce the notion of widespread spatial asynchronicity

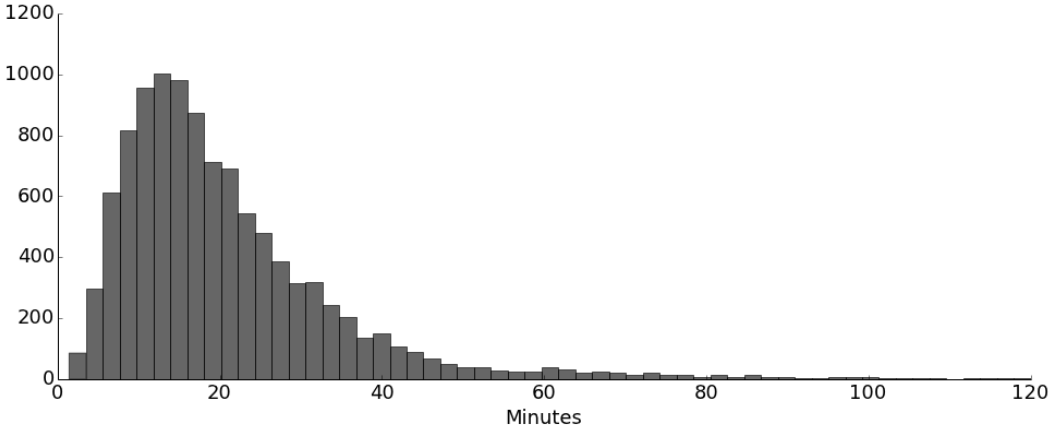
in HeroesX, and they suggest that similar patterns may be evident in other like-structured MOOCs more generally.

Community, Interactivity, and Temporal Asynchronicity

Through the idea of student trajectories, we have established that MOOCs can encounter a high degree of spatial asynchronicity; moving beyond this structural view of a course, we can now examine the presence of temporal asynchronicity and its impact on community and interactivity. Temporal asynchronicity constrains the types of learner-learner and learner-instructor interactions that can occur in a MOOC, and I will argue that this kind of asynchronicity may be more reflective of course design than of student behavior. Although the "always on" nature of MOOCs means that there are always a sizeable number of students online, students can only communicate with one another through the discussion forums, making it difficult to have real-time dialogue. While some students do have lengthy interactions in these forums, most students engage with the course community in limited amounts, if at all.

Temporal asynchronicity stems from students engaging with the course at different times. In traditional brick-and-mortar classrooms, students meet at the same time and for the same duration; MOOCs, on the other hand, are very different. For illustrative purposes, we will again examine HeroesX. Figure 3.3 plots the distribution of average session durations for each student. The vertical axis corresponds to the number of students, and the horizontal axis corresponds to minutes. As is common in MOOCs, this distribution is highly skewed right,

Figure 3.3
Mean Session Duration per Student, HeroesX



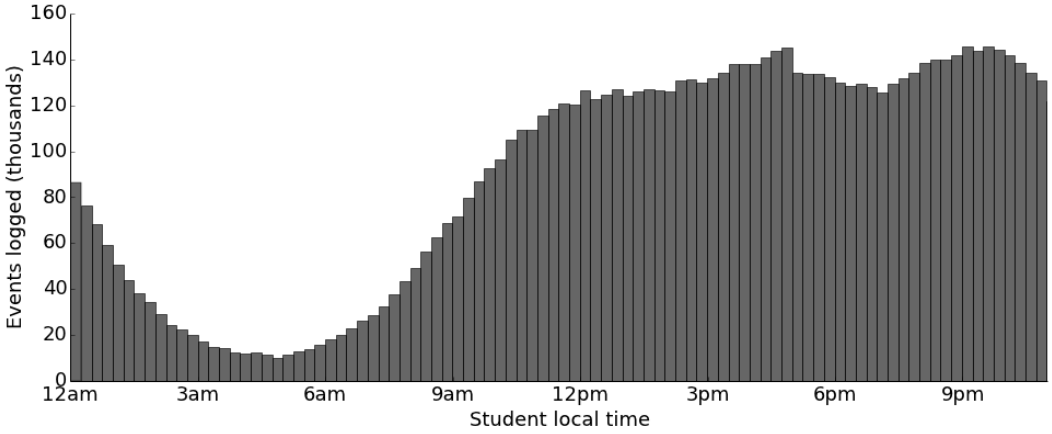
***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* This histogram plots the distribution of per-student mean session durations for students in HeroesX (CB22x, 2013 Spring). This figure only includes students who engaged with the course for at least one hour in order to avoid being overly skewed by the many "shoppers" who only visit the course briefly.

reflecting a tail of a small number of anomalous students with average session durations of up to two hours. More generally, this plot reveals that the sessions of the typical HeroesX student were, on average, between 10 and 20 minutes.[37] Where students in traditional brick-and-mortar classes almost always engage for an hour or more at a time, students in MOOCs like HeroesX tend to engage for shorter intervals. Shorter session times can promote temporal asynchronicity because sessions are less likely to overlap for meaningful durations.

Figure 3.4, on the other hand, shows that HeroesX students are active at predictable times of the day. This distribution has the raw number of course events logged by edX servers (a proxy for activity) as the vertical axis, and the time of day as the horizontal axis in 15 minute bins. As one would expect, activity

[37] See Appendix B for a technical discussion of sessions and these calculations. In short, I have defined sessions according to web advertising standards used by both the Interactive Advertising Bureau and Google Analytics.

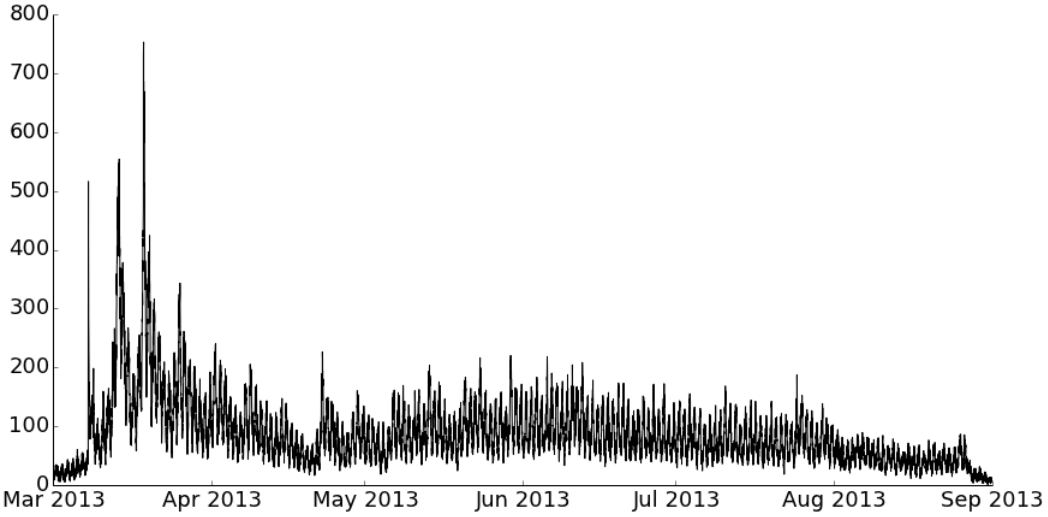
Figure 3.4
Activity by Local Time of Day, HeroesX



***Source**:* Author calculations using primary source HarvardX data and the MaxMind geolocation database.
***Notes**:* This histogram plots the distribution of events in the edX tracking logs for HeroesX by student local times, binned every 15 minutes. Because the edX tracking logs store time in UTC, local times were inferred via IP address geolocation. The MaxMind database was able to match time zones for more than 97 percent of the 9 million log events; the small percentage of remaining, unmatched log events were dropped.

declines rapidly after midnight, hits bottom around 5 AM, and rises steadily throughout the morning. HeroesX students were most active from the early afternoon through the late evening, with distinct peaks around 5 PM and 10 PM (we might hypothesize that the valley between these peaks reflects students being offline for dinner). However, the order and regularity in student activity by time of day has a limited impact on the overall temporal asynchronicity of the course because students in MOOCs like HeroesX hail from all across the world—nearly every country and time zone. In HeroesX specifically, two-thirds of students joined from outside the United States, led by Greece, India, the United Kingdom, and Brazil (Reich et al. 2014a).

Figure 3.5
Number of Students Online, HeroesX



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* This figure plots the number of students online in HeroesX, across 20-minute intervals for the duration of the course. The three peaks at the beginning of the course correspond to an early release (March 8), the public launch of the course (March 13), and the release of Hour 1 (March 18).

So how many students might we expect to be online at the same time? Figure 3.5 plots the number of students online for every 20-minute interval across the 6-month duration of HeroesX. The vertical axis reflects the number of students with activity (anywhere in the course) in a given interval, and the horizontal axis plots absolute time. The three spikes at the beginning of the course correspond to the releases of the first few chapters, and there are smaller peaks for releases of subsequent chapters. More interestingly, there are consistently between 50 and 120 students active in these 20-minute intervals throughout the duration of the course, regardless of time of day or day of the week. Despite the previously described temporal asynchronicity, a student of HeroesX can log on at

virtually any time and expect the equivalent of a large collegiate lecture class to be online, too, though likely scattered across a variety of chapters.

We have established some of the theoretical limits to synchronous student interaction; now we can begin to explore the interactions that actually occur. With reference to the theoretical literature, we can attempt to quantify the levels of learner-learner and learner-instructor interaction, and the extent to which a "community of inquiry" is possible for the students who participate. This analysis will focus on course discussion forums—the official centers for interactive though largely asynchronous dialogue and reflection in most edX MOOCs. In these forums, students can create new "posts" and "comment" on existing ones.

Table 3.1 provides a descriptive overview of forum activity in HeroesX, HeroesX #2, ChinaX, and JusticeX. Although this table reflects a small sample of courses, it offers an empirical basis by which we can begin to understand the degrees of interactivity present in these courses and in MOOCs more broadly. Two notable conclusions emerge from this table: first, a surprisingly large number of students participate in course discussion forums; and second, the two iterations of HeroesX appear to feature richer dialogues between students.

Though MOOCs are often seen as tools for solitary, self-directed learning, thousands of students in these four HarvardX courses chose to post their thoughts publicly: 3,904 in HeroesX, 1,148 in HeroesX #2, 3,697 in ChinaX, and 12,930 in JusticeX. These absolute figures are particularly meaningful when expressed as fractions of the students who engaged substantially with the course more

generally. In short, between 20 and 45 percent of students who spent at least an hour engaging with these courses were active in the discussion forums.

Table 3.1
Summary Statistics for Course Discussion Forums

	HeroesX	HeroesX #2	ChinaX	JusticeX
Students active	3,904	1,148	3,697	12,930
(as % of students spending >1 hour in course)	(27.7)	(20.2)	(39.0)	(44.1)
Student posts	8,364	2,875	9,912	58,535
Student comments	25,286	4,558	10,063	16,763
Staff accounts active	1	10	1	5
Staff posts	69	123	21	110
Staff comments	1,154	2,615	23	1,222
Mean posts per student	2.14	2.50	2.68	4.53
Mean comments per student	6.48	3.97	2.72	1.30
Mean student comments per student post	3.02	1.59	1.02	0.29
Mean staff comments per student post	0.14	0.91	0.00	0.02
Mean comments per thread	3.14	2.39	1.02	0.31
Max comments in a thread	597	229	515	643
Median post word count	58	81	56	66
Median comment word count	32	52	44	46

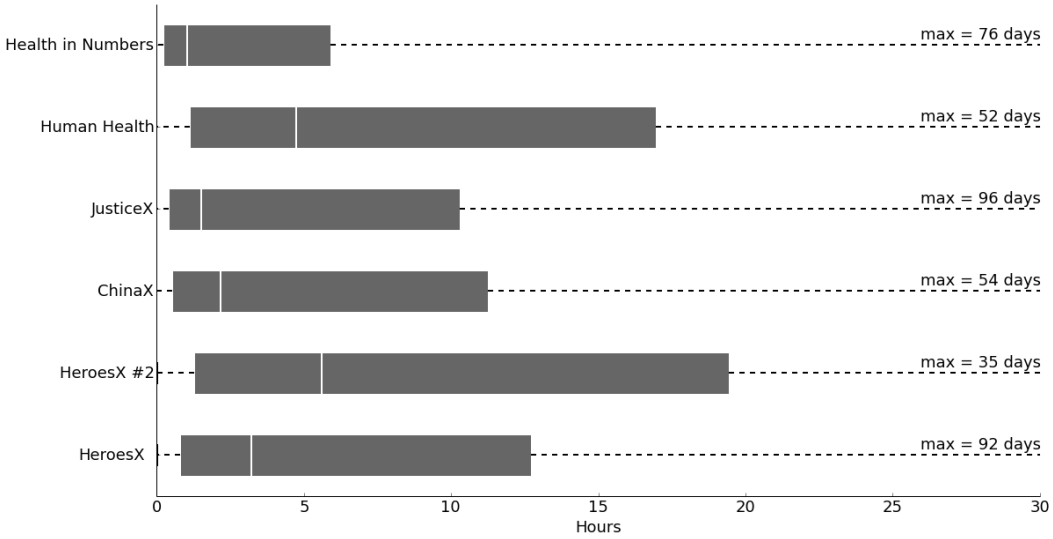
***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* Human Health and Health in Numbers are not included because their forums have been removed from the edX site, and as a result I was unable to generate lists of course staff members. Students are considered "active" in a course's discussion forum if they either post or comment, where posting entails creating a new discussion and commenting entails replying to an existing one. I identified course staff by manually searching the discussion forums for posts and replies with course staff badges, as edX data does not currently distinguish between different types of users.

While a thorough examination of the quality of this forum activity is beyond the scope of this thesis[38], we can develop low-order approximations through these summary statistics. On average, students had few (between two and four) posts and slightly more (between two and seven) comments.[39] Across all of these courses, these posts and comments had median lengths of 30 to 80 words, corresponding to a handful of sentences each. In JusticeX, students posted more than they commented, suggesting that learner-learner interaction and dialogue may have been greater in the other courses (particularly the iterations of HeroesX) where posts garnered one to three student replies on average. For additional texture on the levels of dialogue enabled by course forums, we can look to Figure 3.6, which contains box-and-whisker plots showing how long students had to wait for replies to their posts. Most posts received replies within a matter of hours: more than half of posts with comments received their first reply within five hours, and many received a reply within one hour. Importantly, these forum interactions do not occur in real-time. The delay times in Figure 3.6 reflect the temporal asynchronicity in forum-mediated student dialogue; whether such asynchronous dialogue facilitates or inhibits social learning through Garrison's "communities of inquiry" remains an open question.

[38] A difficult and labor-intensive first step towards analyzing the quality of MOOC forum discussions is the categorization of posts. For instance, it is important to distinguish between questions, answers, and other posts that may be more social in nature (like the large, personal-introduction threads common to most courses). Stump et al. (2013) develops such a coding framework for MITx's "6.002x: Circuits and Electronics," but this remains an open and largely untapped area for further research.

[39] For clarity, "posts" begin new discussions, while "comments" are replies to existing ones.

Figure 3.6
Time to First Forum Reply



***Source**:* Author calculations using primary source HarvardX data.
***Notes**:* Each box-and-whisker plot corresponds to a course, and the horizontal axis indicates the number of hours that elapse between the time that a post is made (starting a new discussion thread) and the time that the post receives its first reply. Whiskers indicate the minimum and maximum time elapsed for a course's forum posts, boxes indicate the 25th and 75th percentiles, and the vertical white lines indicate the medians. Thus, for Health in Numbers, 75 percent of forum posts that received replies did so within six hours. Posts that receive no comments are not included in this plot.

With regard to learner-instructor interaction in the forums, Table 3.1 illustrates a fundamental challenge for MOOC developers: students massively outnumber staff members. Typically, small handfuls of teaching assistants, rather than professors, are active on the forums. While these staff members are highly active (often composing hundreds of replies each over the duration of a course), most student-created threads do not receive direct instructor input.

Altogether, these forum statistics reflect the impact of temporal asynchronicity on interactivity in these MOOCs. A surprising number of students engage with the discussion forums, but these engagements are often limited to a

handful of posts or comments. Course staff members are highly active but cannot be everywhere at once. Dialogue appears substantial, particularly in HeroesX, but in the forums it occurs asynchronously—not in real-time. As we reshape our understanding of the MOOC student from a social standpoint, we should observe that most HarvardX students do not engage with the discussion forums, and those that do tend to do so in relatively limited ways.

Nonetheless, before moving on it is important to acknowledge that the discussion forums are the primary but not only way for students to interact with each other and with the course staff. For instance, in JusticeX, Professor Michael Sandel held two live Q&A sessions in which students could ask questions directly (Reich et al. 2014b). In ChinaX, the professors and course staff held in-person meetups for students near Boston. Both iterations of HeroesX maintained active staff-created, student-created, and language-specific groups on Facebook, Google+, and Twitter. Moreover, this analysis has ignored entirely the mass emails sent from course staffs to students on regular bases. Thus, in focusing exclusively on participation in the official discussion forums, the above analysis offers a substantive but conservative view of the learner-learner and learner-instructor interactions in these HarvardX MOOCs.

Implications for Researchers, Designers, and Instructors

Having established the pervasive presence and impact of spatial and temporal asynchronicity in MOOCs, we can discuss the practical implications for MOOC researchers, designers, and instructors. The central argument of this

chapter is that there is no singular, ideal-typical MOOC student. Conventional conceptions of "students" are in many ways inadequate, and existing approaches often understate or ignore the importance of asynchronicity—a characteristic that shapes the learner-content, learner-learner, and learner-instructor interactions that together construct the student experience. For those who research, design, and offer MOOCs, this analysis yields both caveats and opportunities.

For researchers, this analysis indicates that the task of adequately reconceptualizing "students" in the context of MOOCs is more challenging than one's intuitions would suggest. This chapter's analysis—particularly the development of student trajectories—is simply a starting point, a proof of concept demonstrating that current approaches to categorizing students are incomplete. Beyond the diversity of student backgrounds, intentions, and outcomes, there is an additional dimension of diversity in the pathways students take through these courses. As a result, researchers must be extremely careful in drawing conclusions with reference to MOOC students in the abstract. Even results conditioned upon outcome-defined students (like "active users" or "certificate earners") may fail to capture the deep diversity of trajectories—paths of variable starting point, pace of progress, and regularity—that can produce similar outcomes.

Along similar lines, researchers must be careful in assuming that traditional milestones are meaningful in MOOCs. Consider, for instance, when a student joins a course. In traditional classrooms, it is reasonable to expect that students start progressing through the course (we might say, they start "taking the course") when they join. In MOOCs, this assumption of regular activity is invalid.

It is easy to identify when a student joins a MOOC, but it is less clear when a student actually *starts* engaging with the course in a meaningful way. If we return to Figure 3.1, Student B clearly joins the course mid-May; however, this student's initial activity is brief and limited, and one could argue that this student doesn't actually start "taking" the course until July when he or she begins rapidly and regularly progressing through the chapters of the course. MOOC students can and often do participate at highly irregular intervals, and as a result it is difficult to interpret the significance of temporal milestones as we can in traditional courses.

For designers and instructors, the analyses in this chapter suggest that current MOOCs may be more asynchronous than they need to be. If engaging with students on a weekly basis, MOOC professors and staff members should prepare with the understanding that—particularly in the later weeks of a course—the majority of students will be widely spread across past chapters, even back to the beginning of the course. But despite this asynchronicity, there are important ways in which MOOC students are predictable. Figure 3.5 shows that at any time of the day, any day of the week, and any week of the course, between 50 and 120 students were logged into HeroesX. That so many students are engaging simultaneously (but separately) suggests there is a significant opportunity to build more synchronous interaction into these courses, whether through live chat rooms, status indicators showing who is online, synchronized video watching, or other community-enabling tools. Synchronous and asynchronous peer interactions are not mutually exclusive, and there appears a ripe opportunity to experiment with bridging this gap in MOOCs.

As a concrete example, HarvardX could build online chat rooms into a course and randomly enable the functionality in a pilot experiment to see if having access to such real-time communication tools improves student persistence, satisfaction, and, ideally, learning. Because each chapter of a course has its own topic, we might begin with a separate chat room for each chapter. Already, however, we face the tricky task of randomly assigning students to either a control group, which does not have the chat room functionality, and a treatment group, which does. We know that most students spend no more than a few minutes in the course. Likely, we will not want to include these course "shoppers" in our experiment, so we should wait to launch the experiment until we can identify the students who have demonstrated an intent to engage with the course in more than a fleeting way. But we also know that many students start well after the course starts, and that even the students who do start when the course does often progress irregularly and at varying paces. We likely want our experimental population to reflect this whole range of students, so we might wait to trigger the random assignment for students until they have spent at least 30 minutes on the site. Thus, only students who spend at least 30 minutes in the course will be randomly assigned into our treatment and control groups. Because this assignment is done on a rolling basis, we will have accounted for asynchronicity by avoiding excluding students who join the course late.

Before investing in this experiment, however, we should verify that our experimental population would be large enough to make the chat rooms meaningful (this experiment would be useless, for instance, if we constrained our

treatment group such that only one person were online at a time). Let us consider HeroesX as an exemplar. In HeroesX, 15,112 students spent at least 30 minutes in the course. If we randomly assign half of these students into a treatment group and recalculate the number of students online at any time as we did in Figure 3.5 (ignoring these students until their cumulative time on site reaches 30 minutes, of course), we find that across the duration of the course our hypothetical treatment will have on average 33 students online, and 95 percent of the time it will have more than 10 students online. On the one hand, this is promising for our experiment: we have evidence suggesting that our experiment's treatment group will nearly always have at least a handful students online to engage with one another in the chat rooms.[40] On the other hand, since the number of treatment-group students online typically amount to just a few handfuls, we may want to create just one chat room for the entire course, rather than split students across separate chat rooms for each chapter.

While somewhat technical, the above hypothetical illustrates the challenge asynchronicity poses to MOOC researchers, designers, and instructors. Experiments that sound simple often are not so, and conventional procedures and principles of experimental design do not always translate straightforwardly from traditional classrooms to MOOCs.

[40] Of course, whether or not this handful of online students chooses to be active in a chat room is another question. What this rough analysis has demonstrated is that there are in theory enough treatment-group students online to interact synchronously in a chat room, if they choose to do so.

Summary

This chapter has asked what it means to be a student in a MOOC. Because MOOCs are open and asynchronous, students interact with content, instructors, and other students in ways different from what is common in more traditional, synchronous classrooms. These differences are oftentimes fundamental, and they necessitate a reconceptualization of the MOOC student. MOOC students cannot be properly understood through traditional brick-and-mortar or distance learning modalities because MOOCs allow for far more heterogeneous modes of engagement. Accordingly, this chapter has attempted to advance the reconceptualization of the MOOC student through an examination of asynchronicity and the interactions it permits.

Asynchronicity, interactivity, and openness are inextricably tied. In briefly reviewing the theoretical literature behind these topics, we illuminated their importance vis-à-vis the student experience: asynchronicity introduces tradeoffs in the flexibility and community offered by these courses. Past approaches to defining MOOC students have largely ignored the implications of asynchronicity, instead categorizing students by outcomes as proxies for intentions. In introducing the notion of a student trajectory, we took the first steps toward a new conception of MOOC students that incorporates the variable starting points, paces, and regularities missing in previous categorizations. In exploring temporal asynchronicity through times of student activity and engagement with discussion forums, we established baselines for understanding the levels of learner-learner and learner-instructor interaction possible in these courses. And finally, in

considering the practical implications of these findings, we identified interpretational caveats for researchers and technical opportunities for course designers and instructors. Altogether, these sections paint an incomplete but still richer portrayal of the MOOC student: a deeply diverse collection of behaviors, intentions, outcomes, and experiences.

Conclusion

As platforms like edX expand their reach and schools like Harvard broaden their MOOC offerings, the debate over the transformative power of MOOCs in higher education will hold increasing importance for students, instructors, university leaders, and policymakers. To what degree should schools invest in this new technology? To what extent should governmental policy encourage or discourage these investments? How should students and instructors determine whether these courses are appropriate for themselves? Will higher education be materially different in ten years' time because of MOOCs—either in cost or in effectiveness? These questions help shape what I have called the broader "MOOC debate" and have produced deeply polarized opinions in both academic and informal settings.

Though the arguments that comprise the MOOC debate vary immensely, these arguments tend to employ the same conceptual metrics and vocabularies that are used in more traditional educational settings. For instance, the "efficacy" or "value" of these courses is often posed in terms of conventional retention rates, and the "students" who take these courses are often described in terms of

monolithic categories that reflect the ways students engage with MOOCs' more traditional and synchronous counterparts. This thesis asks whether these conventional metrics and vocabularies are as straightforwardly applicable to MOOCs as these comparisons implicitly assume. Building upon the reconceptualization framework proposed in DeBoer et al. (2013), this thesis finds that retention and asynchronicity are inadequately understood in the MOOC debate and must be reconceptualized for accurate interpretation in the MOOC context. Moreover, this reconceptualization forces us to fundamentally reshape our understanding of "courses" and "students" in these settings.

In Chapter One, we reviewed the surprisingly rich history of distance education. Beginning with nineteenth century correspondence courses and progressing through five technologically defined "generations" of distance education, we found that today's MOOC debate has abundant historical precedent. As far back as correspondence and radio courses in the early twentieth century, scholars suggested that distance learning might have a transformative impact on higher education. Yet to date, this has not happened. In addition to contextualizing the MOOC debate, this chapter identified the characteristics that differentiate distance education from its brick-and-mortar counterpart, as well as the key ways that MOOCs are distinct within the online or distance learning sector. In particular, we found that varying degrees of retention and asynchronicity are not only common issues throughout the history of distance education, but also uniquely pronounced and acute in MOOCs. These findings suggested that retention and asynchronicity deserved further investigation because

they are central to the MOOC debate and they may differentiate MOOCs in fundamental ways. These findings, thus, motivated the next two chapters.

Chapter Two explored the ways existing measures of MOOC retention—generally in the form of registration-based certification rates—inadequately capture the educational value these courses offer to students and to society more broadly. As a reconceptualized supplement to existing course-level measures of retention, which ignore the meaningful educational experiences a student can have in a MOOC without earning a certificate, we considered the idea of modular retention. By treating a MOOC as a series of discrete modules or units, each of which have meaningful educational experiences to offer, we could develop more granular measures of retention that incorporate the experiences of students who only partially "complete" a course. In operationalizing the idea of modular retention through video and discussion retention in HeroesX, we found that these modular retention measures of value are substantially higher than what superficial certification rates might imply. In short, this chapter suggested that the value judgments pervading the broader MOOC debate do not reflect the experiences that MOOCs actually offer; as a potential reconceptualization, this chapter proposed that scholars use combinations of modular retention measures to better approximate the success and value of these courses.

Finally, Chapter Three investigated how asynchronicity arises from openness, shapes interactivity, and defines what it means to be a student. Existing approaches typically define MOOC students by their outcomes—yielding categories like "shoppers" or "explorers" or "completers"—but these categories

ignore the numerous and varied ways students can progress through a course. Within a category like "completers," for instance, we may have students who "attended" regularly every week, students who completed large chunks of the course at irregular intervals, or students who completed the entire course the day before it closed. By failing to incorporate the distinctive asynchronicity in MOOCs, these categories reflect a failure to adequately reconceptualize what it means to be a MOOC student. Our investigation revealed important caveats for researchers and participants in the MOOC debate: foremost, properly defining the "MOOC student" is a deceptively challenging task because a singular, ideal-typical student does not exist. As a result, conclusions about MOOC students—their outcomes, their behaviors, and their motives—should be generalized with extreme caution.

Altogether, these chapters call for significantly more nuance and interpretive vigilance in the MOOC debate. While in some ways similar to the courses, students, and technologies of the past, the MOOC context is also markedly different. If we are to understand and improve upon the MOOCs that interface with higher education today, we must take care to adequately reconceptualize even the most basic ideas for this new terrain.

Limitations and Scope

I began this project with the naïve vision that all MOOCs were roughly the same, and that I would have access to cross-referenceable data for dozens of courses across a variety of schools. In fact, MOOCs come in a wide range of

shapes and sizes, making it difficult to generalize analytical procedures from one course to another, and the data formats and processes that underlie these courses are still under development, making it a challenge to aggregate data from different sources in the first place. The scope of this thesis is thus limited by the state of the art: MOOCs and the data processes behind them are still in their infancy, and while there is an abundance of data *within* courses, it is much harder to gather data that can be compared and contrasted *between* courses.[41] As a result, my datasets were limited to a handful of early HarvardX courses, and my methods were limited to the analysis of observational data.

As with all observational studies with small sample sizes, my findings should be generalized to new MOOC courses and contexts with care. It is not clear, for instance, that the near total asynchronicity present in HeroesX necessarily generalizes to a more scheduled and structured MOOC on Coursera or Udacity, or even elsewhere on edX; further research may be necessary to understand how our definitions of students might change across MOOC platforms. On the other hand, I do maintain that my overall arguments are externally valid across these MOOCs more generally: we cannot use retention and asynchronicity to understand the value and experience of MOOCs the same way we do in more traditional courses. These are the natural implications of courses that are massive, open, and online.

[41] Having so many students and yet so few courses limits the kinds of analyses that MOOC researchers can do and still achieve robust results. If our unit of analysis is a student, even tiny differences will have statistical significance because our sample size is tens or hundreds of thousands. But if our unit of analysis is a course, it is difficult to generate statistically significant results—even if we are able to control for the many ways courses are structurally and contextually different—because our sample size is typically limited to a small handful.

Implications for Future Research

From the outset, this project has aimed to complicate existing analyses and to inspire new ones. Most of this thesis has emphasized the former goal, challenging existing conceptualizations of MOOCs and suggesting reconceptualized alternatives. Before concluding, I would like to summarize and explore a few opportunities for future research raised by this study.

Retention and Value

With regard to retention and the evaluation of MOOCs, the idea of modular retention proposed in Chapter Two represents a first step towards a more holistic reconceptualization of success and value in these courses. This analysis focused on video and discussion retention in a single HarvardX humanities course, HeroesX. Further research is necessary to contextualize the baselines found in this study; to incorporate additional types of student behavior; and to examine the applicability of these measures in courses with different structure. Concretely, are the video and discussion retention rates in HeroesX high or low relative to MOOCs on other topics, in the humanities and otherwise? How can we come up with a measure of modular retention that incorporates the online readings assigned in these courses? Is modular retention a less viable metric in courses with strict deadlines or highly cumulative material? These questions and others remain open for research and will require a larger sample of courses than were available for this study.

Our emphasis on modularity—the idea that students can have meaningful educational experiences in a MOOC without completing everything in the course—also motivates experimentation in course design. Instead of reflecting an entire semester of content, as most MOOCs do, what if a MOOC were split into separate and smaller modules, in the same way that longer lectures are typically split into more digestible chunks? Would such a design make it easier or harder to use retention in approximating a course's value to students? The idea of modularity is already being explored in several new HarvardX courses (ChinaX, for instance, has been split into ten "mini-courses" that run for four weeks each). In developing new MOOCs, we should investigate whether these and other short, modular, and "unbundled" courses offer more value to students through increased flexibility, or more clarity to researchers through further discretized experiences.

Above all, however, our examination of certification and modular retention suggests that the best measure of success, value, or even completion in a MOOC should be tied to the amount a student learns. Most MOOC students are interested in learning rather than earning a certificate, and it is intuitive to think that the amount of knowledge gained by students in a MOOC is a meaningful representation of the value the course added to society. Yet learning is incredibly difficult to measure. One way to estimate the amount a student learns is to offer before-and-after testing. Students could take a diagnostic test to approximate their knowledge when they first enter the course, and subsequent tests after every "module" of the course could use this baseline to approximate what the student learned by engaging with that module. This inference is not straightforward:

designing a fair and representative diagnostic test is challenging, and as with certification-based retention rates, reliance on tests may ignore the value derived by students who are more interested in simply consuming content. Regardless, research around before-and-after testing in MOOCs appears a worthwhile contribution to the development of more meaningful measures of value in MOOCs.

Asynchronicity and Interactivity

With regard to asynchronicity, interactivity, and the ways we conceive of MOOC students, the analyses in Chapter Three offer foundations for thinking about new ways for edX to design courses and new ways for researchers to create student cohorts. In spite of the broad spatial and temporal asynchronicity evident in courses like HeroesX, the global scope of these courses means that there is always a substantial number of students online. In current MOOC designs, these students have no way to communicate and coordinate in real-time, even though they are engaging with the course simultaneously. Given the theoretical emphasis on social and community-based learning, there seems to be an opportunity to experiment with new functionality like "chat rooms" that might allow students to engage with one another more synchronously. Investment in the development of such tools seems worthwhile, as do experiments designed to explore whether these synchronous, community-building tools impact outcomes like retention—modular and otherwise.

Our investigation of student trajectories likewise revealed opportunities for further research. In particular, this analysis posed a challenge for researchers to define more meaningful student cohorts. We have seen, after all, that students who "start" in the same week can have very different trajectories through a course, and as a result it might not make sense to think of these students as being in the same cohort. Our examination of student trajectories in HeroesX suggests that as a starting point, we may want to explore clustering or grouping students by the nature of their trajectories to come up with a simplified model for the different ways students move through a MOOC. For instance, can we cluster student trajectories by starting point, pace of progress, and regularity? Further research is necessary to identify the vast number of different ways to engage with a course, and to simplify these modes of engagement into meaningful categories and models so that researchers can generalize their findings to student populations across courses.

Looking to the Future

One a more speculative note, while this thesis does not choose a side in the MOOC debate that frames our investigation, I believe this thesis has demonstrated one way these courses can be beneficial—if not transformative—in higher education more broadly. In this thesis, I have endeavored to show that common assumptions about what MOOCs are, how they work, and what their students do, are often incomplete or incorrect. MOOCs force us to reconsider fundamental ideas about what constitutes a "course," a "student," or a valuable

learning experience. Yet, our survey of the past "generations" of distance education has shown us that these various technologies and ideologies progress through dialogue. Rather than exist in a vacuum, the various modes of education interact and influence on another. The dialectic of traditional online education and OpenCourseWare gave rise to MOOCs, and already MOOCs are engaging in active dialogue with more traditional modes of education. In the form of "flipped" classrooms, for instance, MOOCs are questioning the efficacy of the large lecture model that pervades most universities today. Whether through massive open online courses, "flipped" classrooms, or some other manifestation, the MOOC debate is encouraging students, instructors, institutional leaders, and policymakers around the world to challenge the assumptions that underlie traditional forms of education. If all MOOCs ever do is push us to reexamine the aspects of education we take for granted, they may well be the root of something truly transformative.

Appendix A
HarvardX Courses in This Study

Short Name	Long Name	Term	Duration	Registrants
Health in Numbers	PH207x: Health in Numbers: Quantitative Methods in Clinical & Public Health Research	Fall 2012	13 weeks	61,170
JusticeX	ER22x: Justice	Spring 2013	21 weeks	79,740
HeroesX	CB22x: The Ancient Greek Hero	Spring 2013	17 weeks	43,555
Human Health	PH278x: Human Health and Global Environmental Change	Summer 2013	12 weeks	53,335
HeroesX #2	CB22.1x: The Ancient Greek Hero	Fall 2013	17 weeks	14,639
ChinaX	SW12x: China (Part I)	Fall 2013	4 weeks	22,205

***Notes**:* All six of these courses are online adaptations of courses taught on campus at Harvard University. Health in Numbers and Human Health are from the School of Public Health, while the other four courses are from the Faculty of Arts and Sciences. This study includes all HarvardX courses that finished before the end of 2013 with the exceptions of CS50x: Introduction to Computer Science and HLS1x: Copyright, which were excluded because the data available for these courses were incomplete.

Appendix B
Estimating Session Durations

Estimates of "time spent" across various course components represent a key contribution of this thesis. In the past, MOOC researchers have generally relied on event counts (e.g., the number of times a student accessed a page), rather than the richer and more intuitive notion of time spent (e.g., the amount of time a student spent on a page). Because edX log data simply amounts to a list of events, event counts are more straightforward to compute and require fewer assumptions. On the other hand, relying solely on event counts ignores valuable information about the duration of student engagement. (Consider that a student could visit a page for as little as 3 seconds or as long as 30 minutes, and in either case this activity would count for just one event.)

Calculating time spent on webpages is challenging because site logs do not record when students become inactive. For example, whenever a student navigates to a new page, an event is recorded in the logs. While we can infer how much time was spent on a page by the time difference between events, we will often be unable to determine the time spent on the *last* page a student accesses. Fortunately, this problem is well documented in the web analytics literature, and we can draw upon research from online advertising companies like Google, whose profitability depends on making these kinds of inferences.

Google, the Interactive Advertising Bureau (IAB), and a variety of other online advertisers define a "session" as "a single continuous set of activity

attributable to a cookied browser or user."[42] Importantly, sessions are assumed to have ended after an "inactivity threshold," for which the industry standard[43,44] is 30 minutes. In other words, if a user is inactive for more than 30 minutes, the user's session is considered over and the time spent on the user's most recent action is ignored. The table below illustrates these calculations for an imaginary user:

Raw Log Events			Calculated	
Time	**Action**	**Resource**	**Time Spent (mins)**	**Session ID**
1:30:00	page_view	Page A	1	1
1:31:00	page_view	Page B	4	1
1:35:00	page_view	Page C	--	1
9:10:00	page_view	Page A	20	2
9:30:00	page_view	Page C	etc.	2

By using this session-based framework, we can generate reasonable estimates for the amount of time students spend in the course, in the forums, and on particular course pages. This information is valuable and more easily interpretable than event counts, but researchers must be aware of the 30 minutes inactivity threshold assumption behind it. If, for instance, a student legitimately spends more than 30 minutes on a page without clicking anything, we will ignore this activity. However, at least for the HarvardX courses considered in this study

[42] Interactive Advertising Bureau, 2009, "IAB Audience Reach Measurement Guidelines," February 23, accessed February 28, 2014, http://www.iab.net/media/file/audience_reach_022009.pdf.
[43] Ibid.
[44] Google, 2013, "Google Analytics Cookie Usage on Websites," January 16, accessed February 28, 2014, https://developers.google.com/analytics/devguides/collection/analyticsjs/cookie-usage.

(and particularly HeroesX), this assumption seems reasonable: none of the course videos in HeroesX lasted more than 20 minutes, so course pages containing videos should not naturally produce more than 20 minutes of "inactivity." Likewise, while a student could conceivably spend a great deal of time composing a forum response before clicking "post," we have seen that the majority of forum posts are only a few sentences and likely did not take more than 30 minutes to compose. For the average student, thus, we have little reason to deviate from the industry standard inactivity threshold of 30 minutes.

Appendix C
Estimating Video Completions

Like estimates of time spent, estimates of video completions (i.e., the fraction of students who watch a video to completion) represent an important contribution of this thesis. Past research (Ho et al. 2014; Seaton et al. 2014) has largely relied on video event counts (e.g., the number of times the user clicks "play"), implicitly equating starting a video with finishing it. From a pedagogical perspective, however, starting and finishing a video are materially different: we can be much more confident that a student meaningfully engaged with a video if we know he or she not only started it, but watched it to completion. Because videos are the primary way content and instruction are delivered in MOOCs, this distinction is very important.

Unfortunately, determining whether a student completed a video is more challenging than simply summing the number of times he or she clicked "play." Video events are not always logged accurately: they can, for instance, be recorded out of order or redundantly. These inconsistencies may arise from server glitches, erroneous browser-side AJAX requests, students refreshing pages, students using multiple tabs, or likely a host of other reasons. Regardless of the reason, these inconsistencies make it difficult to trace precisely how a user watches a video—when they pause, speed up, skip ahead, etc.—and it also casts doubt upon the meaningfulness of raw event counts as more than a rough measure of a student's video watching activity.

With a few assumptions, however, we can come up with estimates of how far students got into each video. Because video events include a "playback_position" field and because a "pause" event is typically fired when a video ends or the student navigates away, we can take the furthest playback position for a student in a given video as a reasonable measure of how far the student progressed in that video. Since we know the duration of each video, we can express a student's playback position as a fraction of the total video length, and we can use this fraction to estimate the number of students who completed each video. In this thesis, I assume students have "completed" a video if their furthest playback position is beyond 95 percent of its duration.

This approach is useful, but as always we must carefully consider the assumptions it makes. Importantly, simply relying on the furthest playback position logged for a user leaves us vulnerable to students seeking (i.e., skipping) forward or backward within a video. If a student skips ahead to the end of a video, we will estimate that he or she completed the video when in reality he or she did not actually watch it. However, I do not believe this is a significant issue in the HarvardX courses examined in this thesis. In particular, of the 20,983 different usernames that logged a video "play" event, only 638 ever logged a "seek" event. In the logs, there are 36 times as many "play" events as "seek" events, and of the "seek" events, about half are skips forward and half are skips backward. Moreover, more than 80 percent of video "seek" events move no more than one minute in either direction. As a result, we have reason to believe that a student's furthest playback position in a video can yield a sensible estimate of whether he

or she finished it; and even if we find these assumptions troubling, this approach is no less dubious than relying on raw event counts as researchers have done in the past.

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