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MOOC research: some of what we know and avenues for the future

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Introduction

As I write this, it has been exactly three and a half years since November 2011, when I sat in a meeting with a group of MIT (Massachusetts Institute of Technology) faculty, all of whom are leading educators in their field, and MIT's then-Provost, now President, Rafael Reif, as he described his idea for a wide-scale online learning platform. Three months earlier, two Stanford University professors, Sebastian Thrun and Peter Norvig, had launched an online course on artificial intelligence, which ultimately enrolled 160 000 students and landed them on the front page of the *New York Times* [1,2]. President Reif suggested calling his new initiative, MITx, but that name was changed to edX in spring 2012, when Harvard joined with MIT to lead the non-profit consortium of universities that would develop and teach edX MOOCs (massive open online courses). However, the goals of edX have remained the same as Reif outlined that day: to democratize education as well as extend research into computer science and into learning.

A decade earlier, in 2000, MIT had launched OCW (OpenCourseWare), a repository for material from almost all of MIT's 2000 courses, including syllabi, readings lists, problem sets and exams (all OCW offerings can be found at http://ocw.mit.edu/index.htm). But for several years before the introduction of MITx, faculty, specialists in online learning and administrators at MIT had been exploring ways to make online offerings more interactive and collaborative. Similar work was being done at Stanford. According to an informal history of the development of xMOOCs[2] by Andrew Ng, a co-founder of Coursera, one of the three leading xMOOC platforms, since at least 2007, both Stanford and non-Stanford researchers had been experimenting with the infrastructure that would be needed for scalable online learning [3]. At MIT, much of this work was being undertaken by faculty and researchers in the CSAIL (Computer Science and Artificial Intelligence Laboratory). The challenge was to create courses that hundreds of thousands could participate in at once. The courses would be composed of online videos,

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[2]The field makes a distinction between c (connectivist) MOOCs and xMOOCs. The former refers to courses designed to connect students so they can construct their own knowledge; cMOOCs were first developed by George Siemens, Stephen Downes and David Cormier. xMOOCs were the next wave of courses that appeared on platforms such as Coursera, edX and FutureLearn. They are built on a more traditional model of university teaching with disciplinary experts – usually faculty – providing the content. Much of the early writing on MOOCs was about cMOOCs, but since 2012, almost all research has centred on xMOOCs.

lectures and discussion forums that would be highly interactive. A system to grade homework assignments and exams by machine also needed to be developed, as human instructors would not be able to do the grading if enrolments were as high as these early pioneers hoped.

MIT's first MOOC was 'Circuits and Electronics' (6.002×) built from a required on-campus introductory course of the same name. 6.002× opened enrolment in March 2012, and, eventually, over 154 000 students registered for it, and over 7000 earned a certificate after completing the 14-week course. The summer after the first iteration of 6.002× was completed, the unit I then headed, the MIT TLL (Teaching and Learning Laboratory), was funded by the U.S.A.'s NSF (National Science Foundation) to use the data that the edX platform had collected to begin to understand the phenomenon of MOOCs. Those data comprised over 230 million interactions, including the activities of each student as he or she accessed any one of the course components; scores on homework assignments, laboratories and exams; almost 100 000 posts on the discussion forum; and the results of a survey sent to some students at the end of the course. The purpose of the research was to try to understand "who the students were in 6.002×, how they utilized course resources, what contributed to their persistence, and what advanced or hindered their achievement" ([4], p. 14).

The initial research on xMOOCs (2012–2013)

That research resulted in a publication in spring 2013, *Studying Learning in the Worldwide Classroom*. It complemented early research on Coursera MOOCs done at Duke University [5], the University of Edinburgh [6] and the University of Pennsylvania [7]. Common among the findings of those studies was that rates of attrition were high in MOOCs, with often half of those registering never engaging with the course at all, and, on average, under 10% (and often as low as 4–5%) of the enrollees completing it. A specific finding of [4] that garnered interest both in the field of educational research and in the press was that the strongest correlation between student background factors and achievement, defined as receiving a certificate, was whether a survey respondent reported he or she "worked offline with anyone else on the… …material" (p. 20).

Some of the initial research on MOOCs was funded by the Bill and Melinda Gates Foundation as the MOOC Research Initiative, led by George Siemens, now executive director of the LINK (Learning Innovation and Networked Knowledge) Research Lab at the University of Texas at Arlington. That campus was the site of a meeting held in December 2013, attended by 200 researchers where many of the early findings of the Gates Foundation-funded studies were reported [8]. Shortly after the Texas meeting, in March 2014, the first Learning@Scale conference was held. "Inspired by the emergence of massive open online courses", L@S was organized by the U.S. ACM (Association of Computing Machinery). The conference's goal was "to promote a scientific exchange of interdisciplinary research at the intersection of the learning sciences and computer science" [9], and the third annual conference will be held at the University of Edinburgh in spring 2016. Yet another avenue for research on MOOCs is the International

Education Data Mining Society; at the 2015 conference, there were a dozen papers or presentations on research related to MOOCs [10]. Much of the research activity in Europe has been reported in the EMOOCs Summits held in 2013, 2014 and 2015 [11,12], as well as the conference held in May 2015 that generated the present volume. High-impact journals, primarily in the area of educational technology and distance education, in which MOOC research has appeared include the *British Journal of Educational Technology*, *Computers & Education*, *Current Issues in Emerging eLearning*, *International Journal on E-Learning*, *Journal of Interactive Online Learning* and the *Communications of the ACM*, as well as discipline-specific journals on teaching and learning (e.g. *Journal of Geography in Higher Education* and *Physiotherapy*). The book *MOOCs and Open Education Around the World* was published in 2015 [13].

The second wave of research (2014–2015)

Since that initial work on xMOOCs was done in 2013, there has been an outpouring of studies. A search on ERIC (Educational Resources Information Center), a U.S.-funded repository for educational research, found 20 papers on MOOCs before 2013. According to the MOOC Research Literature Browser, amassed by the U.K.'s Katy Jordan, that number rose to just over 50 in 2013 and almost 200 in 2014 [14]. Liyanagunawardena, Adams and Williams [15] studied the published literature from 2008 to 2012, and identified 45 peer-reviewed papers in that period. My own search on Google Scholar in August 2015, for articles with the words MOOC or MOOCs in the title, without the filter of peer review, resulted in just over 2900 articles in 2012–2014, and 1300 articles so far this year. If output for the last four months of 2015 remains at a similar level to the first eight months of this year, approximately 1500 articles or papers will be published in 2015.

This chapter is an attempt to summarize the focus of at least a subset of this research. In reviewing the articles on both the MOOC Research Literature Browser and Google Scholar, it is clear that much of the published literature are descriptions of the individual experiences of instructors who developed a MOOC. Many disciplines that compose the offerings of a traditional university have been made into MOOCs: writing, physics, electrical engineering, cartography, to name just a few. There are also MOOCs in professional fields, including medicine, law, public health, management, library and information science, and education. The geographic diversity of MOOC instructors is apparent, with faculty from Europe, including the U.K., the U.S.A., Australia, South America, India, Japan, Georgia, Turkey and China writing about their motivations to create a course, the challenges of developing one and the experience of instructing thousands of students at one time. There has been a small stream of research and essays that have explored the particular meaning of MOOCs in and to the developing world ([16] and see a special section in [17]). Several studies have also attempted to report on MOOCs from the students' perspective usually by reporting on survey data [17–19].

There is any number of ways that the articles about MOOCs can be categorized. Liyanagunawardena et al. [15] grouped their review of the research

from 2008 to 2012 into eight 'areas of interest', including educational theory, participant-focused and provider-focused. Gasevic et al. [20], when reviewing the papers from the MOOC Research Initiative conference in 2013, classified those initial papers into five categories: student engagement and learning success; MOOC design and curriculum; self-regulated learning and social learning; social network analysis and networked learning; and motivation, attitude and success criteria.

I and my research collaborator, Purdue Professor Jennifer De Boer, in preparing a literature review for a publication we are writing, reviewed articles on MOOCs that focused on the educational experiences that MOOCs afford students, particularly studies that explore ways to increase persistence, experiments with pedagogy and what contributes to student achievement. We have separated out from the research on pedagogy those studies that focus specifically on the discussion forums because they are such a different phenomenon than the more 'conventional' pedagogies that have been adopted by MOOCs such as video lectures or multiple-choice tests. Indeed, one of the claims early MOOC proponents made was that they would connect students who were far-flung from each other geographically, and the discussion forums are the 'place' where that happens. Thus we have clustered MOOC research into three groupings: who the students are, why and how they persist, and pedagogical methods, differing from both Liyanagunawardena et al. [15] and Gasevic et al. [20] because of the specific lens we are applying. Running through these three groupings, we realize, are two threads: first, that the technology itself has an impact on the organization and instrumentation of MOOCs, allowing for some kinds of pedagogical methods and experiences and disallowing others; and, secondly, that many MOOC researchers are experimenting with different methods of analysing data collected by the platforms since the form and amount of those data have not been available to educational researchers previously.

Below I describe some of the research findings in each of our categories, and then I offer some speculations about what might be interesting questions to explore. What is not included in this discussion is the economics of MOOCs, specifically costs associated with production, marketing and maintenance of courses; the politics surrounding MOOCs either on campus or in other arenas; and what MOOCs might mean for the future of education, although these areas have been the subject of considerable interest both in the research literature and in the popular press.

Who are the students?

In 2011 and 2012, when MOOCs were more an idea than a reality, no one had a real grasp on what kind of students would enrol in them or how users might benefit from interacting with MOOCs. The hope was that by developing courses from elite, primarily (at that time) U.S. institutions, people who did not, and would never, have access to that level of education would be able to avail themselves of it. Much was made, for example, of the fact that a 15-year-old student from Mongolia had a perfect score on the 6.002× assignments and

exams; he was eventually enrolled as a full-time on-campus student at MIT. He exemplified the promise of MOOCs.

However, that hope has yet to be broadly realized. As was the experience with 6.002×, the demographics of MOOC students, particularly of certificate-earners, is quite different from that expected. Although there was wide geographic diversity in 6.002× (registrants came from 194 countries), most certificate-earners had advanced degrees, were older and came from backgrounds where education was stressed [4]. Similar findings have been replicated in many studies of MOOC participants. For example, the first-year report from edX included demographics of typical users who accessed the original 17 courses: they were male with Bachelor's degrees and were 26 or older [21]. Research from the University of Pennsylvania found "the student population tends to be young, well-educated and employed" ([22], p. 1). edX's second-year annual report detailed growth in these same demographics: participants aged 30 years and above increased from 40% to 47%; those with bachelor's degrees grew from 65% to 71%; and U.S.A.-based students expanded from 27% to 32%. There was a rise in female participants, however, from year 1 to year 2 from 14% to 19% ([23], p. 9). In response to criticism that MOOCs were not fulfilling their promise, Schmid et al. [24] argue that, even though these are the dominant demographics of MOOC users, among the millions who have studied on the hundreds of MOOCs produced, there are "some for whom this is their only way to access a rigorous, college-level course" (p. 1). They explore MOOC usage among those under 18 and those over 65, and those who had limited access to educational possibilities, offering a more optimistic view of MOOCs than has been reported for the most part in the press (see, e.g. [25]).

Still, the *very* low completion rates of MOOCs, I think it is fair to say, surprised MOOC pioneers and promoters. Clow [26] called the phenomenon the "funnel of participation", and we definitely saw that funnel in 'Circuits and Electronics' (6.002×): the numbers fell from 154763 who initially registered for the course, to 26347 who tried the first problem set, 10547 who made it to the midterm exam, 9318 who passed the midterm exam, 8240 who took the final exam, and 7157 who earned a certificate (data provided by edX and gratefully acknowledged). MOOC supporters contend that reporting these low completion rates distorts the true picture of what is happening with MOOCs, as well as their impact. I call this the 'denominator debate'. For example, Daphne Koller, the co-founder of Coursera, and her co-authors Ng, Do and Chen, in a widely circulated article that appeared in *EDUCAUSE Review* [27], maintained that it was unfair to calculate completion rates on the basis of the number of people who registered for a course as many of those individuals never intended to take the course in the first place. And, in fact, subsequent research has shown that only half of those who register for a course ever click on it at all. But researchers still debate who should 'count' as a 'student' when the final rendering is done. Someone who clicked once on the course site? Someone who viewed a majority of the videos? Someone who did at least half of the coursework? However the field decides to judge the worth of MOOCs, the fact that attrition was, and remains, very high motivated research using predictive modelling to attempt to identify who was likely to drop out before they did so and suggesting possible interventions, as well as pedagogical experiments to try to improve persistence.

Who persists?

Studies on MOOCs have attempted to understand more fully who persists in these courses, why some students do persevere (are there commonalities in those students' background, motivation or patterns of interaction?), and what leads to stop out. Kizilcec, Piech and Schneider [28] researched this question as early as 2013, based on three computer science MOOCs, mapping what they called "longitudinal engagement trajectories". They noted what others have subsequently seen: that is, that learners stay connected to the course by watching videos even though they do not necessarily take the assessments. They suggested that, as a way to increase engagement, assessments could be downplayed by instructors, or even eliminated entirely, if students indicated at the beginning of the course that they were only enrolling for their own satisfaction or mastery of the material. Another early experiment by Wilkowski, Deutsch and Russell [29] involved periodically reminding students of their own goals, which they had identified at the start of the course, but that seemed to have little effect.

The problem of low completion rates was the topic of a number of preliminary reports at the MOOC Research Initiative conference in December 2013. Whitmer, Schiorring, James and Miley [30] made remedial writing in English the focus of their research, classifying learners as disengaged, declining, lurking or persisting[3]. They found no correlation in student background or motivation for taking the course with the students' level of participation; however, they did discover that students who took a survey at the beginning, as well as a learning-readiness quiz, remained in the course longer [30]. They speculate that those activities may increase engagement because students recognize their own deficits in writing and are motivated to improve [30]. Other research looked at factors associated with time (i.e. when students accessed material and what their orientation towards time was) [32], persistence by gender and by country [28], or by the reputation of the provider [33], to see whether any of those variables had any impact on persistence [34].

Two particularly good studies that draw on what is known from 'conventional' educational research may provide the best clues for how to develop and teach MOOCs. Kizilcec and Halawa [34] looked at "goal striving, growth mindset and feelings of social belonging" (p. 57). They call on the work of well-respected educational researchers such as Tinto ([35], as cited in [34]), and Walton and Cohen ([36], as cited in [34]) to remind MOOC researchers that these scholars have identified critical ingredients in student achievement. Analysing data from 20 MOOCs, they report that students who achieved more in the courses overall showed higher levels of goal-striving in general, that students who said they were more satisfied with the course also reported that they felt they belonged, and that students who progressed well indicated a growth mindset. They write:

[3]There have been numerous attempts to classify MOOC learners according to their level of activities. For example, Anderson et al. [31] developed a five-class taxonomy of viewers, solvers, all-rounders, collectors and bystanders.

> "*this pattern reflects differences in the underlying process by which these psychological factors shape learner behaviour and perceptions. Social belonging related to feeling comfortable and connected in the learning environment, whereas mindset relates to one's ability to master demanding materials.*" ([34], p. 64)

Similarly, Poellhuber et al. [37] examined the motivation of MOOC students relying on previous research in education, particularly Pintrich's work (see, e.g. [38]), as well as Bandura's research in self-efficacy (see, e.g. [39]). Although they only analysed data from one course in economics taught in French, they found that students, who reported self-efficacy for the subject, as well as strong intrinsic goals for mastering the material, persisted more in the course [37]. MOOC researchers would do well to take guidance from these well-substantiated findings in educational research.

Experimenting with pedagogy

MOOC instructors, usually in collaboration with developers and researchers, have experimented with a number of pedagogical methods within their MOOCs. Some of these experiments have been undertaken to increase persistence and/or engagement (particularly on the discussion forums[4]), although others have been implemented to explore the affordances that the new platforms allow. These experiments have included: using badges to incentivize discussion forum activity to some positive effect [41]; releasing course content in stages rather than all at once, with 'ontrackness' more prevalent in the latter [42]; investigating the effect of students beginning the MOOC with friends or colleagues, which correlated positively with course completion, achievement and discussion forum activity [43]; and asking students to discuss their answers to multiple-choice questions in groups of three synchronously [44].

One excellent example of pedagogical design was implemented with 8,500 students in over 20 courses on Coursera and Open edX. The instructional team relied on two additional peer learning platforms to illustrate the importance of interdependence to course participants, strengthening their interactions and helping instructors to guide discussions more effectively [45]. Other approaches tested motivating peer-graders [46] or mentors [47], connecting video watching with access to the textbook in a group setting [48] and strengthening peer grading [49]. Unfortunately, it is not possible as yet to draw definitive conclusions about the best pedagogical methods to use in MOOCs, as instructors and developers are still very much in an experimental mode.

[4]Typically, only a small number of MOOC users post on the discussion forums. For example, in 6.002×, 2.7% of all students asked a question, 3.9% answered a question, and 3.3% made a comment. Participation was much higher for certificate earners (27.7%, 40.6% and 36.0% respectively), and there was a mild significant correlation between the number of posts/certificate earners and total score in the course [40].

Testing data analysis techniques

As noted above, another stream of the research has been devoted to testing a variety of sophisticated statistical methods that are possible because of the volume of data collected by the MOOC platforms. For example, Nesterko [50] includes a long list of such techniques (e.g. naïve Bayes, random forest, Latent Dirichlet Allocation and Support Vector Machine) to explore whether diverse students groups who used course components varied in their course completion rates and grades. Yang et al. [51] describe a new method they used – text and graph clustering – to examine social interaction in MOOCs. Several researchers have experimented with A/B testing in which different methods of instruction 'compete' against each other. For example, Tomkin and Charlevoix [52] compared two MOOCs on sustainability, assigning students randomly to one of two conditions. In one version, there was no instructor participation, but, in the other, the instructor and the teaching assistants were present in the discussion forum and provided weekly summaries of feedback. There were no statistically significant differences in student achievement, rates of participation or student satisfaction, although students in the version with instructor presence earned more badges for forum completion [52] (see [53] for another experiment based on A/B testing). Although some educational researchers feel A/B testing holds a great deal of promise, it has not yet been widely implemented, probably because of the challenges associated with it. As mentioned above, there is also a robust strand of research that employs statistical models to attempt to predict which students will stop out of the course; often the authors of these studies then suggest interventions that could then be designed to increase the rates of completion [54].

It is evident that there has been a tremendous amount of effort that has gone into MOOC research, and much of it done as collaborations between instructors, who are the domain specialists, and the programmers and developers, who are the experts at creating the tools and features on the platforms to strengthen the learning experience of MOOCs students. Williams and Williams [55] provide a strong argument in favour of this collaborative approach and an eloquent description of what this kind of collaboration could accomplish. It is a strategy that I believe has a great deal of potential. That said, Margaryan, Bianco and Littlejohn [56], in a recent article, rated 76 randomly selected MOOCs using commonly accepted instructional design principles; they found that the educational quality of those MOOCs was quite low. Evidently, we still have a way to go.

Speculations on future research

When the MOOC phenomenon began at MIT in 2012, I was asked to be on a working group that was to explore 'basic research' in education, and how MOOCs could contribute to it. By the beginning of 2013, members of that working group, along with other MIT faculty and researchers, had generated a 20-page document that was primarily a list of the research questions that could be asked. These questions were divided into six themes: the characteristics of the students,

instructional strategies and learning behaviours, the assessment of learning, the use of feedback, social networks and collaborative learning and teaching, and new research possibilities and methods. As I write this short review of the research that has been accomplished in the ensuing three years, I'm gratified to see that progress has been made in each of those areas. But there is so much more to do.

The question that is foremost in my mind, and upon which any speculation about future research lies, is whether MOOCs, as originally conceived, will be viable in the future. We have already seen some indications that the MOOC providers may be centring their efforts on professional education, particularly in the fields of technology and management. There also seems to be a move towards shorter learning experiences. Although the first iteration of 'Circuits and Electronics' (6.002×) lasted 14 weeks, there is only one edX MOOC that will launch in September that is longer than 8 weeks, and all of the MOOCs highlighted on Coursera's homepage are between 5 and 7 weeks in duration. Still, MOOCs closely parallel traditional on-campus courses in orientation and format: that is, an instructor delivers content with assessments to test learners' knowledge.

How might MOOCs evolve in the future? Is there a possibility that xMOOCs might return in some way to the original goals of the cMOOCs, i.e. to remove the instructor from the centre of the experience and give students greater opportunities to build their own knowledge? Or might MOOCs adopt a more modular approach, with learners choosing 'morsels' of learning based on very individual needs and interests, which they can then assemble into their own 'course'? The future of MOOC research will depend a great deal on the forms that develop, but those forms will be based, in part, on what the research shows us. MOOCS are evolving phenomena, and their evolution will depend on the continued close collaboration among the research community, teachers and the technology designers who have a common goal of advancing and improving digital learning.

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