Staggered Versus All-At-Once Content Release in Massive Open Online Courses: Evaluating a Natural Experiment

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ABSTRACT
We report on an experiment testing the effects of releasing all of the content in a Massive Open Online Course (MOOC) at launch versus a staggered release. In 2013, HarvardX offered two “runs” of the HeroesX course: In the first, content was released weekly over four months; in the second, all content was released at once. We develop three operationalizations of “ontrackedness” to measure how students participated in sync with the recommended syllabus. Ontrackedness in both versions was low, though in the second, mean ontrackedness was approximately one-half of levels in the first HeroesX. We find few differences in persistence, participation, and completion between the two runs. Controlling for a students’ number of active weeks, we estimate modest positive effects of ontrackedness on certification. The revealed preferences of students for flexibility and the minimal benefits of ontrackedness suggest that releasing content all at once may be a viable strategy for MOOC designers.

Author Keywords
MOOCs; natural experiment; ontrackedness; synchronicity

ACM Classification Keywords
K.3.1 Distance Learning.

BACKGROUND AND CONTEXT
One of the distinctive features of open online courses is their asynchronicity. Most credit-bearing courses, whether residential or online, have a registration date, a start date, a drop-date, an end date, and a series of due dates for assignments and exams along the way. These structures create a synchronous cohort of students who proceed through a course at roughly the same pace; “falling behind” in this synchronous regime is considered a warning sign for students. As a result, many learning analytics systems are designed to rapidly identify off-pace students, so they can be remediated [1]. By contrast, many non-credit-bearing online learning environments are totally asynchronous. Students can engage with Khan Academy or MIT’s OpenCourseWare at any pace, and these platforms make no efforts to support a synchronous community of learners.

Many of the MOOCs offered on platforms like edX and Coursera walk a middle ground between the tight synchronicity of credit-bearing residential courses and the total asynchronicity of OpenCourseWare. MOOCs have what might be described as “partially asynchronous” structures. They include mechanisms to encourage synchronicity, but without the strict pacing typical of credit-bearing courses. MOOCs have start dates, but students can often also register late without penalty. Some courses have intermediate due dates, but many MOOCs have only a final due date at the end of the course. Some courses sequentially release content every week, which prevents people from racing ahead but allows laggards to catch up. Other courses release all materials at once, a model akin to hosting open courseware with an auto-grading mechanism and a final due date. Some courses use norming mechanisms—such as recommended syllabi and reminder emails—rather than enforcement mechanisms to keep students moving as a cohort. Indeed, Cormier in his original video definition of a MOOC describes such a course as “an event,” but one in which students are admonished to “find your own path” [2].

Partially asynchronous MOOCs attempt to balance two competing and worthy goals. On the one hand, instructors try to create a sense of community by encouraging students to progress as a cohort. When students move at the same pace, discussion forums can offer a sense of ongoing dialogue, and course teams can produce “office hours” videos and other media to address common issues raised in a given week. Many programs in computer-supported collaborative learning, where online tools help students learn with and from their peers [11], depend upon nearly synchronous peer interactions. From this perspective, the signature advantage of online learning environments is the ability to leverage peer networks at scale [10].

On the other hand, these time-based structures are not necessary in many MOOCs—especially when computers can automatically assess student work at any time—so some instructors attempt to accommodate learners’
schedules by offering flexibility in completing the course. From this perspective, the signature advantage of using computers in education is to personalize student learning. Staker and Horn define blended learning as learning that allows students some measure of control over “time, pace, path or place” [12]. In this vision, technologists hope that permitting students to choose their own path and pace will enable them to optimize their individual progress and learning. Early research on course-taking patterns in MOOCs indicates that students often do proceed through courses in non-linear ways, particularly by moving forward to assessments and then backwards to relevant lecture material [4]. Whether exercising this flexibility produces better student learning outcomes remains an open question.

The effects of MOOC course design on community-building or individual flexibility are little understood, in part because of the nature of access to MOOC data. While most MOOCs serve many thousands of students, few researchers have data from more than a dozen courses. Thus, while researchers can conduct rich investigations of individual variation within courses, comparisons between courses are limited by the paucity of public data [6]. For example, Nesterko and colleagues examined the relationship between the use of strict due dates in MOOCs and course completion rates, and they found a modest positive correlation [8]. But the ten courses they examined differed not only by their use of due dates, but also by their enrollment size, subject matter, university affiliation, and many other dimensions. Researchers need data from hundreds of courses to begin drawing reasonable inferences about cross-course differences from naturalistic observation.

While cross-course MOOC research awaits greater university collaboration, one way that researchers can study the impact of course design is by exploiting the methodological opportunities afforded by repeat runs of the same course. In this study, we address several questions about the tradeoffs between community-centered and individual-centered design by taking advantage of a natural experiment conducted in 2013 with the HeroesX course offered by HarvardX on the edX platform. In the first version of the course, the content was released in weekly or semi-weekly bundles over five months between March and August of 2013. In the second version of the course, the content was identical, but it was all released on the course start date in September 2013. From this natural experiment, we can evaluate the impact of one mechanism for enforcing partial asynchronicity—the timed release of content—on student behavior and performance.

Student ontrackness, which we define as the degree to which students cohere with the recommended syllabus in a course, is one important dimension of student behavior. A perfectly on-track student will move through the course at exactly the recommended pace, whereas a student with low ontrackness will move at a highly idiosyncratic pace. In Figure 1, we illustrate the wide variation in ontrackness in HeroesX by showing sample pathways of six students who completed the course and earned a certificate with very different paces. We plot calendar time on the x-axis, and the 27 chapters—high-level organizational units of the course called “Hours”—on the y-axis. Each circle represents a session of time spent in a chapter, and larger circles indicate longer sessions. None of these six students display perfect ontrackness; a student perfectly on-track would have the bulk of their time each week following the grey line that represents the release of content. Student C comes closest: though C has a late start in mid-April, by early May, the student consistently spends time on the most currently released units. By contrast, students A and F both start on-track, but then fall behind. Student A catches up to being on-track towards the end of the course, whereas Student F takes a six week break and then makes a major push to finish. Students B and E both start quite late, remain well behind the release of content, but ultimately finish the course. That six students with very different course-taking patterns all completed the course provides a proof of concept that students with low ontrackness can complete a course, and that when given flexibility in course pacing, at least some students will take advantage. However, there remain open questions as to whether such flexibility is desirable and whether students are more likely to persist, participate, learn, or earn a certificate if the structures of a course encourage or compel students to stay on-track.

To investigate the effect of different content-release paradigms (sequential versus all-at-once) on students’ ontrackness, we investigated data from the two versions of HeroesX with two research questions. First, does releasing all content at the beginning of a course lead to more individual variation in student progress and less ontrackness? Second, are these changes consequential? Can we identify benefits to staying on-track in a course even when instructors allow for individual variation in path and pace? In addressing these questions, we propose novel...
THE HEROESX NATURAL EXPERIMENT
Since 1978, Professor Gregory Nagy has taught a General Education course at Harvard University on conceptions of the hero in ancient Greek literature. In 2013, Prof. Nagy adapted the most recent version of that course into a MOOC. HeroesX: The Ancient Greek Hero first launched in March of 2013 as the third HarvardX course offered through the edX platform [9]. The goal of the course is to address the question, “What does it mean to be human?” by examining one model of humanity, the ancient Greek hero. The course is designed to invite both novices and committed Hellenic scholars into a community of inquiry exploring the world described by ancient Greek texts.

HeroesX is divided into 24 chapters called “Hours” (corresponding to lecture hours in the residential class), plus two introductory chapters and one concluding chapter. Each Hour includes a package of materials, such as video lectures from Nagy, dramatic readings of ancient texts from students, and discussions among Nagy and course staff. These videos are complemented by readings in two online books. The Ancient Greek Hero in 24 Hours guides student learning through the material, and the Sourcebook of Original Greek Texts Translated into English includes all 55 primary sources from the course. Each Hour also includes two sets of assessment questions: Content Questions test a student’s recall of important features of the texts, and Annotation Exercises evaluate a student’s ability to interpret ancient texts. These two sets of multiple-choice assessments have four questions each, amounting to a total of eight questions per Hour. Students must earn a grade of at least 50 percent on these questions to earn a certificate for the course.

Registration for the first version of HeroesX opened on December 19, 2012, and the course opened 83 days later on March 12, 2013. When the course launched, not all of the content was finished, so it was released at a rate of roughly two chapters per week, though delays occasionally meant a week would go by without new content. Regular messages to participants announced the arrival of new content, creating a sense of shared syllabus. All content was available by July 24, 2013, and students were given until August 26, 2013 to complete assignments in consideration of a certificate. While the sequential release of content created a ceiling on how quickly students could progress, no due dates or other structures prevented students from falling behind or enrolling late. A student who registered on the final day of the course could still earn a certificate. When the course finished, 43,563 students had registered for the course, and 1,399 students had earned certificates, yielding a completion rate of 3.2 percent for all registered students.

Even before the completion of the first version (v1) of the course, the HeroesX course team announced plans for a second run (v2). On August 7, 2013, registration opened for HeroesX v2, which launched on September 8, 2013.

In terms of content and sequence, HeroesX v2 was almost identical to v1. Because of the short turnaround between the two runs of the course, there was no time to make substantive changes to the content. Structurally, however, HeroesX v2 differed from v1 in several important ways: for instance, v2 had a shorter registration window and a smaller enrollment. The most important difference, however, was that content was released all-at-once, rather than sequentially.

In ideal experimental conditions, the timing of content release would be the only difference between the two course runs; unfortunately, this was not the case. Table 1 compares v1 and v2 in terms of timing, demographics, content, and other features of the course. HeroesX v2 had a much shorter registration window than v1 and had far fewer students; only 22,975 online students registered for v2 before the course ended. The composition of student bodies, however, was quite similar. Both populations had a median age of 30, a median level of education of a Bachelor’s degree, and slightly more men than women.

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The second course run also included several smaller populations of interest. The courseware for HeroesX v2 was used simultaneously by three groups of learners: students registered for the residential version of the course in Harvard College (n=236); students registered for a credit-bearing online version of the course in Harvard’s Division of Continuing Education (n=37); and edX students online (n=22,975). The two credit-bearing groups proceeded along a defined syllabus, which also guided the edX students. Regular emails and messages from the course staff announced the Hours that were featured in the credit-bearing courses each week, creating a set of norms around course pace but providing no strict controls for edX students’ pacing. Residential students were also assigned that week, the previous week, or the next week. In any week of either version of HeroesX students were spending the plurality of their time in Hours 0 and 1, the introductory material to the course. Some of these students getting a late start (such as students B and E from Figure 1), but many of these students are “shoppers” [3] who examine introductory materials but never return. As the course advances, student activity becomes more diffuse and spread out across the various Hours. By Week 8, most students were spending the plurality of their time “off-

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<th>Released</th>
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<tr>
<td>17</td>
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<td>Afterword</td>
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<tr>
<td>21</td>
<td>(None)</td>
<td>Hour 24</td>
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<td></td>
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</tbody>
</table>

Table 2: Strict and loose ontrackedness in the idealized schedule from HeroesX v1

illustrates these definitions for the closing weeks of v1. These two definitions of ontrackedness allow us to conduct at least one form of sensitivity analysis on our findings.

In the first version of HeroesX, three trends characterized student pathways through the course: staying on-track, progressing off track, and “shopping.” In Figure 2, we show where students spent the plurality of their time in each week of the course. On the x-axis we show the week relative to course launch, and on the y-axis we plot the 27 chapters for the course. For each week, we estimate the time spent on each chapter by each student by examining the event logs from the edX platform. For each student, the time spent on a chapter is the sum of the time differences between events in that chapter, excluding differences greater than 30 minutes, an inactivity threshold standard in the web analytics literature [5, 7] From these estimates, we identify the chapter of the course that students spent the plurality of their time in for each week. In Figure 2, each student contributes to one circle per week—to the circle corresponding to the chapter where he or she spent the plurality of his or her time. Thus, a large circle on Week 1, Hour 0 indicates that a large fraction of students spent the plurality of their time in Week 1 in Hour 0.

Three important groups can be seen in Figure 2. Chapters that are strictly and loosely on-track are shaded in dark and light gray, respectively, and a distinct cluster of students proceeds on-track with the release of content. In every week of the course, there is a separate cluster of students spending the plurality of their time in Hours 0 and 1, the introductory material to the course. Some of these are students getting a late start (such as students B and E from Figure 1), but many of these students are “shoppers” [3] who examine introductory materials but never return. As the course advances, student activity becomes more diffuse and spread out across the various Hours. By Week 8, most students were spending the plurality of their time “off-

BEHAVIOR AND ONTRACKEDNESS IN HEROESX

The pathways of students in HeroesX v2 were much more diverse, and much less on-track, than the pathways of students in HeroesX v1. We demonstrate this finding in three parts. First, we clarify what it means to be on-track in a given week of the course. Second, we offer descriptive visualizations illustrating that far fewer active students in v2 were on-track compared with v1. Finally, we define several operationalizations of student-level ontrackedness to quantify these differences and link to student outcomes.

In any week of either version of HeroesX, some chapters are defined as on-track. In HeroesX v1, we define chapters as strictly on-track if they were released that week; likewise, in v2, we define chapters as strictly on-track if they were assigned that week in the course’s recommended schedule, thus corresponding to the pace of the residential students. For both versions of the course, we define chapters as loosely on-track if they were released or assigned that week, the previous week, or the next week. In effect, there is a one-week buffer on either side of the schedule (note this buffer only extends backwards in v1 because future content wouldn’t be released yet). Table 2

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track.” So even though several mechanisms, like sequential content release and regular emails, attempt to keep students on-track, asynchronous pacing was the norm rather than the exception by the middle of the course.

Figure 3 shows the same distribution of time for all HeroesX v2 students who were not enrolled in either of the two credit-bearing options. The visual difference with v1 is stark. First, the dense cluster of activity defined by the sequential release of content in v1 diminishes substantially. The cluster of activity around the schedule defined by the syllabus of the course becomes very faint, and from the early weeks of the course, student activity is already widely distributed across all chapters of the course. As with v1, though, a cluster of “shoppers” (and late entrants) in Hours 0 and 1 is visible in every week. The activity of students in the online version of HeroesX v2 contrasts sharply with the behavior of residential HeroesX v2 students, shown in Figure 4. Here, notice that residential students maintain almost perfect synchronicity with the course syllabus until exam preparations begin in Weeks 14 and 15.

A potential limitation of these visualizations is that each student is assigned to a single chapter (and circle) each week. Even if a student spends his or her time relatively evenly across many chapters in a given week, he or she only counts towards one of the circles. As a result, we complement our scatter plots with two additional visualizations that address this limitation. In Figure 5, we show the unweighted average time spent by students across the course each week in three categories. Time spent in Hour 1 and earlier is defined as “Shopping”; time spent loosely on-track is defined as such; and time spent in all other chapters is defined as “Elsewhere.” Each week, we calculate the fraction of time spent by each active student across these three categories, and then we plot the average percentage time spent in each category for each week. (Note that in the first few weeks, time spent shopping overlaps with time spent loosely on-track, so this time is counted twice.) As with the trio of scatter plots, Figure 5 shows the striking difference in time allocation between the students in HeroesX v1, the edX students in HeroesX v2, and the credit-bearing students in HeroesX v2. Time spent loosely on-track in HeroesX v1 is noticeably higher than that in HeroesX v2. By contrast, nearly all of student time is spent loosely on-track for most of the credit-bearing, residential version of HeroesX v2. Again, in both v1 and v2, there is a substantial fraction of student time spent “shopping” each week, and the fraction of student time spent neither shopping nor on-track increases rapidly in the first 8 weeks of both courses, and then steadily after that point.

To characterize how our analyses might change with strict and loose definitions of ontrackedness, in Figure 6 we plot the fraction of active students who spent the plurality of their time in strictly and loosely on-track chapters. Between 30 and 40 percent of students are at least loosely on-track in
most weeks in v1, and the proportion of those who are strictly on-track varies. In v2, by contrast, 20 percent or fewer of edX students are loosely on-track during the course, and very few are strictly on-track until the end, while college students in the HeroesX v2 were by far the most synchronized.

So far we have examined ontrackedness through the perspective of a course week, but we can also evaluate the overall ontrackedness for each student. Summarizing a student’s ontrackedness is challenging because students often start at different times, are on-track one week and off-track the next, skip certain weeks of the course, and finish the course in different weeks. Consequently, we propose three possible operationalizations, shown in Table 3.

In the first two definitions of student ontrackedness, we consider weeks spent on-track. First, we define ontrackedness as the proportion of weeks, after a student starts, with the plurality of time spent in on-track chapters. Since this measure includes all weeks a student is active in the course, it “penalizes” students who skip weeks or finish early. Thus, in our second operationalization we examine the proportion of active weeks (weeks with at least one log event) where the plurality of time is spent on-track, excluding the first two weeks of the course. We exclude these weeks because of the large numbers of “shoppers” at course launch who briefly view the first two chapters and then leave.

We can also examine student ontrackedness by calculating the proportion of total time, rather than weeks, spent on-track. In our third operationalization in Table 3, we show the fraction of total time spent in chapters defined as on-track, excluding the first two weeks. This metric could be

<table>
<thead>
<tr>
<th>Operationalization</th>
<th>v1</th>
<th>v2 (online)</th>
<th>v2 (college)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Proportion of weeks after first activity with plurality of time on-track</td>
<td>0.0190 (n=24,782)</td>
<td>0.0052 (n=11,457)</td>
<td>0.2331 (n=236)</td>
</tr>
<tr>
<td>(2) Proportion of active weeks with plurality of time on-track (excluding first two weeks)</td>
<td>0.0594 (n=17,773)</td>
<td>0.0249 (n=6,959)</td>
<td>0.3174 (n=235)</td>
</tr>
<tr>
<td>(3) Proportion of total time spent on-track (excluding first two weeks)</td>
<td>0.0552 (n=17,773)</td>
<td>0.0227 (n=6,959)</td>
<td>0.3233 (n=235)</td>
</tr>
</tbody>
</table>

Table 3: Mean student ontrackedness, by three operationalizations
biased by students who spend an inordinate amount of time in a single on-track chapter, but the similarity between operationalizations (2) and (3) suggests this is not the case.

By each of these operationalizations, we find that students in HeroesX v1 exhibit greater ontrackedness than those in v2. These differences are statistically significant ($p < 0.001$) and substantial: across all operationalizations, students in HeroesX v1 spent about twice as much time on-track as students in v2. Both students in v1 and the edX students in v2 were far less on-track than the residential students in v2. The majority of college student time in all operationalizations was at least loosely on-track.

**WAS THE DECREASE IN ONTRACKEDNESS CONSEQUENTIAL?**

In the previous section, we showed that student course-taking behaviors in HeroesX v2 showed substantially more variation than in HeroesX v1, and that fewer students in v2 spent time on-track than in v1. The next key question for researchers, practitioners, and students is whether or not these changes are consequential. Was HeroesX v2 improved or weakened by releasing all content at the beginning? Who might have benefited and who might have been harmed?

When looking across the two courses as a whole, we see very few differences in performance, persistence, and participation across the two versions of the course. In Table 4 we display several aggregate measures of these categories: certification rate, median grade, mean days of activity in the courseware (defined as discrete 24 hour UTC-demarcated periods with at least one event log), mean hours on site, mean videos watched, the percentage of students active on the forums, and the mean posts and comments per forum-using student. Generally, these measures are very similar between the two runs of the course. The certification rate, hours on site, and video watching behavior are slightly higher in v2. The proportion of students using the forums at least once, and the number of posts per active forum user are slightly higher in v1. In comparing the two edX versions of HeroesX from this high-level view, it appears that the bundle of changes made between the versions of HeroesX (the shorter registration window, the smaller course size, the inclusion of credit-seeking Harvard college students, the return of participants from v1, the release of all content at once, and the additional experience of the course team) had minimal impact on persistence, performance, and participation. It is possible that some elements within that bundle of changes might be counteracting each other, and that certain positive changes might be rendered unobservable by negative ones.

Figure 7, for instance, shows that the two versions of HeroesX had very different distributions of weeks active for certificate earners, suggesting that the parity in overall certification rates may mask underlying mechanisms that impacted student performance. On the whole, however, the high level statistics about the course suggest minimal differences in student outcomes.

One critical caveat to this observation is that we have very little insight into student learning from each version of the course. While HeroesX assessments may be very thoughtfully designed as assessments for learning, they have a variety of undesirable properties as assessments of learning (as highly structured multiple choice questions that follow a particular format, suitable for the application of test-taking strategies). Although participation, performance, and participation may be proxies for learning, the degree to which they lend themselves to making valid inferences about student learning is unknown [9].

<table>
<thead>
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<th>v1</th>
<th>v2 (online)</th>
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<td>Active students</td>
<td>24,905</td>
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<td>57</td>
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<tr>
<td>Certification rate</td>
<td>0.056</td>
<td>0.057</td>
<td>0.242</td>
</tr>
<tr>
<td>Median grade (excluding grade=0)</td>
<td>0.090</td>
<td>0.100</td>
<td>0.260</td>
</tr>
<tr>
<td>Persistence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median days active</td>
<td>3</td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td>Median hours on site</td>
<td>0.673</td>
<td>0.777</td>
<td>22.525</td>
</tr>
<tr>
<td>Mean videos watched</td>
<td>7.934</td>
<td>6.718</td>
<td>10.127</td>
</tr>
<tr>
<td>Participation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students active on forums</td>
<td>3,190 (12.8%)</td>
<td>869 (7.6%)</td>
<td>226 (95.8%)</td>
</tr>
<tr>
<td>Mean posts</td>
<td>3.130</td>
<td>2.509</td>
<td>4.146</td>
</tr>
<tr>
<td>Mean comments</td>
<td>8.127</td>
<td>8.272</td>
<td>1.456</td>
</tr>
</tbody>
</table>

Table 4: Aggregate statistics of performance, persistence and participation for active students in HeroesX v1 & v2.
One way to examine the effect of the all-at-once content release on course outcomes in HeroesX v2 is to specifically examine how ontrackedness relates to student course performance, and then to examine whether there appear to be any benefits or costs associated with staying on or falling off track. If there are substantial benefits to staying on-track, then the marked decrease in ontrackedness in HeroesX v2 might be seen as problematic.

To begin to address this question, we estimated a series of logistic regression models examining the relationship between weeks on-track and certificate attainment, shown in Table 5. In Model A, we present a baseline model including the proportion of weeks active, course version (coded as “0” for the Spring version 1 and as “1” for the Fall version 2), and an interaction term. We find that there is a significant, positive relationship between weeks on-track and certification, and a complex interaction between version and weeks active. For all students, there is a positive relationship between weeks active and certificate attainment. The negative term on the interaction between version and weeks active indicates that for students with few weeks active, students in v2 are more likely to earn a certificate, but for students with many weeks active, students in v1 are more likely to earn a certificate. This finding is consistent with the distributions of certificate attainment by weeks active shown in Figure 7. Computing adjusted risk ratios from these logit parameter estimates, we estimate that students active in 75 percent of weeks are 17 times more likely to earn a certificate than students active in 25 percent of weeks.

In the subsequent six models, Model B through Model G, we include an additional term for each of our three approaches to measuring ontrackedness (each proportions that can range from 0 to 1), with both strict and loose definitions. We also include an additional interaction term between version and weeks on-track. The results are very similar across all six models. In all models, the proportion of weeks active is a stronger predictor of certification than the proportion of weeks on-track. The proportion of weeks on-track is positively associated with certificate attainment.

### Table 5: Taxonomy of logistic regression models predicting completion rates by six operationalizations of ontrackedness, controlling for the proportion of weeks active and course version.

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
<th>Model C</th>
<th>Model D</th>
<th>Model E</th>
<th>Model F</th>
<th>Model G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-5.537**</td>
<td>-5.406**</td>
<td>-5.429**</td>
<td>-5.311**</td>
<td>-5.321**</td>
<td>-5.239**</td>
<td>-5.247**</td>
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<tr>
<td></td>
<td>(0.079)</td>
<td>(0.079)</td>
<td>(0.079)</td>
<td>(0.084)</td>
<td>(0.084)</td>
<td>(0.082)</td>
<td>(0.082)</td>
</tr>
<tr>
<td>Version</td>
<td>0.851***</td>
<td>0.767***</td>
<td>0.774***</td>
<td>0.845***</td>
<td>0.91***</td>
<td>0.816***</td>
<td>0.851***</td>
</tr>
<tr>
<td></td>
<td>(0.115)</td>
<td>(0.115)</td>
<td>(0.115)</td>
<td>(0.129)</td>
<td>(0.128)</td>
<td>(0.126)</td>
<td>(0.115)</td>
</tr>
<tr>
<td>Active</td>
<td>(0.175)</td>
<td>(0.227)</td>
<td>(0.197)</td>
<td>(0.189)</td>
<td>(0.18)</td>
<td>(0.199)</td>
<td>(0.175)</td>
</tr>
<tr>
<td>Ontrackedness Proportion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.175)</td>
<td>(0.227)</td>
<td>(0.197)</td>
<td>(0.189)</td>
<td>(0.18)</td>
<td>(0.199)</td>
<td>(0.175)</td>
</tr>
<tr>
<td>Active Weeks on Track</td>
<td>2.773***</td>
<td>4.957***</td>
<td>0.869***</td>
<td>2.104***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.299)</td>
<td>(0.411)</td>
<td>(0.134)</td>
<td>(0.168)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Time On Track</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.102***</td>
<td>1.379***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.146)</td>
<td>(0.204)</td>
<td></td>
</tr>
<tr>
<td>Version* Weeks Active</td>
<td>-1.812***</td>
<td>-1.179***</td>
<td>-1.134***</td>
<td>-1.606***</td>
<td>-1.423***</td>
<td>-2.051***</td>
<td>-1.596***</td>
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<tr>
<td></td>
<td>(0.274)</td>
<td>(0.323)</td>
<td>(0.296)</td>
<td>(0.292)</td>
<td>(0.286)</td>
<td>(0.299)</td>
<td>(0.289)</td>
</tr>
<tr>
<td>Version* Ontrackedness</td>
<td>2.317**</td>
<td>4.373***</td>
<td>0.56*</td>
<td>0.218</td>
<td>1.07***</td>
<td>0.666</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.72)</td>
<td>(1.191)</td>
<td>(0.227)</td>
<td>(0.332)</td>
<td>(0.241)</td>
<td>(0.389)</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>36738</td>
<td>36738</td>
<td>24732</td>
<td>24732</td>
<td>24732</td>
<td>24732</td>
<td>24732</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.5592</td>
<td>0.5641</td>
<td>0.5398</td>
<td>0.5334</td>
<td>0.5292</td>
<td>0.5319</td>
<td></td>
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<tr>
<td>Log Likelihood</td>
<td>-3485</td>
<td>-3446</td>
<td>-3228</td>
<td>-3274</td>
<td>-3303</td>
<td>-3284</td>
<td></td>
</tr>
</tbody>
</table>

Note: Cell contents are logits and (standard errors). * $p < .05$ ** $p < .01$ *** $p < .001$
The most striking difference between HeroesX v1 and v2 is
material over time. In the first version of HeroesX, which
released course content in a staggered fashion over several
months, a cohort of students stayed on-track with the
syllabus throughout the course, but many students pursued
their own individually paced pathways through the material.
After the first few weeks of the course, the majority of
students spent the plurality of their time in chapters other
than the most current, assigned chapters. In HeroesX v2,
where all content was released at once; this asynchronicity
was even more extreme, and nearly all online edX students
pursued their own individual paces throughout the course.
By several measures of ontrackedness, students in the
second version of HeroesX were on-track half as much as
students in the original. The pacing of edX students in
HeroesX v2 stands in stark contrast to the Harvard students
enrolled in credit-bearing courses using the same
courseware, who moved through the material in lockstep.
While these differences in pacing are striking, their effects
on student attainment are substantively modest (though
statistically significant). In all of our models of certificate
attainment, the strongest predictor of certification is weeks
active. Students with many weeks active were slightly more
likely to earn a certificate in v1, and students with few
weeks active were slightly more likely to earn a certificate
in v2. This may simply reflect that the full release of the
content in v2 allowed students to finish with fewer weeks of
effort—whereas students in v1 were forced to return after
many weeks to see the full content. Staying on-track in both
v1 and v2 had a small positive effect on certificate
attainment. From the narrow perspective of certificate
attainment (which again, we must be careful not to treat as a
perfect proxy for learning), staying on-track appears
preferable to being off-track. These effects, however, were
modest, and they may not apply equally to different types
of learners. Moreover, the better performance of those who
stayed on-track must be weighed against the revealed
preferences of students whose actions indicate that they
prefer a more flexible schedule.

From these findings, we offer three observations for course
developers and faculty in creating open online courses.
First, we suggest that instructional designers should assume
that students will take advantage of any flexibility offered
to proceed at their own pace. Even in courses with a
recommended syllabus and norming mechanisms to
encourage students to follow that syllabus, course
developers should assume that most students will not stay
on-track. Collaborative activities and discussions should
assume a dimension of asynchronicity that can extend over
the whole length of the course run.

A second important, if somewhat incidental, finding from
our investigations is that in every week of the course, a
substantial portion of visitors engage with the very first
contents of the course. For many students, it is the only part
of the course they see. Faculty and course teams should
consider carefully, therefore, how they use this privileged

CONCLUSION: GUIDELINES FOR COURSE
DEVELOPERS AND DIRECTIONS FOR FUTURE
RESEARCH

The most striking difference between HeroesX v1 and v2 is
seen in the variable student pathways through the course

in all models. The first operationalization of ontrackedness,
the proportion of weeks on track, has the largest positive
parameter estimates and the third operationalization, the
proportion of active time on track has the smallest
parameter estimates. Parameter estimates are smaller for the
loosely on-track definitions relative to the strictly on-track
ones. In all models, the interaction term with version and
weeks active is negative, and the interaction term with
version and weeks on track is positive (though not always
significant) indicating that the effect of ontrackedness is
stronger for students in v2 than in v1.

To illustrate these interactions, we display plots of six
prototypical groups of students in Figure 8, drawn from
Model E, where ontrackedness is defined as the proportion
of active weeks a student spends the plurality of his or her
time strictly on-track. We chose this model since the
parameter estimates were in the middle of the range of
effect sizes. Students in v1 are displayed in solid black, and
students in v2 are displayed in dashed grey. For each
version of the course, we plot the effect of ontrackedness
(the x-axis) on the probability of earning a certificate (the y-
axis), for students who are active 20 percent of course
weeks, 50 percent of course weeks and 80 percent of course
weeks. Notice the substantial gaps between the line pairs,
indicating the strong effect of weeks active on predicted
certificate rates. The effect of ontrackedness (the slope of
these lines) is modest at low and high levels of weeks
active, and more substantial for students with half of weeks
active. Students with 20 and 50 percent weeks active have
higher predicted certificate probabilities in v2, while
students with 80 percent weeks active have higher predicted
certificate probabilities in v1. Although the nuances of
version and ontrackedness are of interest, the most striking
finding is the positive effect of weeks active on predicted
certification probabilities in both versions of HeroesX.

![Figure 8: Predicted certification rates by proportion of active weeks strictly on track for six prototypical students.](image-url)
piece of educational real estate, both to entice students to stay in the course but also to make a meaningful impact on students who might only engage with that small portion of content. One possible approach might be to have the first chapter of a course summarize the important ideas from the whole course, rather than simply introducing the first topic to be discussed.

Finally, for those course developers considering whether to release content in stages versus all-at-once, we found very few differences in student performance, persistence, or participation resulting from changing the pattern of content release. Increasing flexibility does lead to having fewer students stay on-track, and there does appear to be some evidence of modest benefits to keeping students on-track in terms of certificate attainment. Thus, there appears to be at least a modest tradeoff between offering students greater flexibility and encouraging students to stay on-track, where they are slightly more likely to complete the course. If we can make any statement with confidence, it is that students will take advantage of whatever flexibility in pacing is offered. There appear to be advantages to returning to the courseware over multiple weeks, suggesting that even if students don’t stay on-track, engaging frequently from week to week is correlated with certificate attainment.

It is important, however, to return to the caveat that we did not comprehensively examine all possible student outcomes. We cannot definitively say that staying on-track enriches student learning, only that staying on-track has a modest positive correlation with earning a certificate in HeroesX. We also cannot comment on changes to the overall quality of the learning experience resulting from greater flexibility. For instance, one reason for keeping students together as a more synchronous cohort is to enrich the quality of online discussions. While we saw no evidence of major changes in the proportion of students participating in discussions or in the quantity of participation from each student, we did not measure the quality of student discussions. These would be fruitful avenues for further research.

Moreover, while the particular conditions of the HeroesX natural experiment, especially the stability in the content of both offerings, made it an interesting site for examination, no study of a single course can generalize to the full range of MOOC offerings. Courses in different subjects and with different structures—different assessments, stricter due dates—might be differentially impacted by structures that increase student flexibility in completing the course.

There are many MOOC faculty and course developers who have completed one run of a course and are pondering a repeat run. For faculty in those circumstances considering releasing all of their content at the beginning of the second run, our research offers some guidance. For those who wish to maximize student flexibility, releasing all content at once appears to allow students more flexibility in their pathways through a course. For those who wish to keep students as a more synchronous cohort, our findings suggest that releasing all content at once will further diminish the size of the student cohort that proceeds through a course on-track, and that there may be modest benefits to keeping students on-track.

REFERENCES