# The Peril and Promise of Pre-tests in Informal Massive Open Online Courses

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## ABSTRACT

*With more than 100,000,000 learners from around the world, massive open online courses (MOOCs) are a popular online learning resource. Because this type of online teaching and learning is relatively young, published MOOC research is not as voluminous as traditional educational research. This presents both a challenge and an opportunity. The challenge is that best practices are not always clear, and there is not much MOOC research upon which to draw for specific instructional design strategies. The opportunity is to harness the power of MOOC platforms themselves to conduct research that examines and identifies effective digital pedagogy. In this chapter, the authors describe some of these challenges and opportunities. Specifically, they draw upon a multivariate experimental research study (Janelli, 2019; Janelli & Lipnevich, in press) that examined the effects of pre-tests and feedback on learning and persistence in a MOOC. They offer practical implications that are related to study findings.*

Keywords: American Museum of Natural History, Assessment, Coursera, Educational Technology, Feedback, Informal Online Learning, Massive Open Online Courses (MOOCs), Our Earth's Future, Pre-tests

## INTRODUCTION

With more than 100,000,000 learners from around the world (Shah, 2018), Massive Open Online Courses (MOOCs) are a popular self-guided online learning resource. Because this type of online teaching and learning is just a few years old, published MOOC research is not nearly as voluminous as traditional teaching and learning research. This presents researchers and educators with both a challenge and an opportunity. The challenge is that best practices are not always clear, and there is not much information upon which to draw for specific, evidence-based instructional design strategies. The opportunity is to harness the power of the MOOC platforms themselves to conduct experimental studies that examine and identify effective digital pedagogy to ensure that learners enrolled in MOOCs achieve their desired goals.

MOOCs became popular around 2012 (Pappano, 2012) and the number, variety, and contexts in which MOOCs are used continue to increase. After all, how convenient is it to be able to explore a topic of interest without ever leaving the comfort of your home? One can "attend" lectures given by the best instructors from the best schools and pick and choose which course materials to study. Besides the obvious flexibility and affordability of MOOCs, what differentiates them from traditional courses is the exorbitantly high attrition rate. Researchers report that the average rate of attrition in MOOCs is between 92 and 97% (Hew & Cheung, 2014; Williams, Stafford, Corliss, & Reilly, 2018), whereas the average attrition rate among full-time undergraduate students is approximately 19%. In 2016, the freshmen retention rate in higher education was 81% with a six-year graduation rate of 60% (Undergraduate Retention and Graduation Rates, 2019).

In this chapter we describe some of these challenges and opportunities in greater detail. Specifically, we draw upon a recent study (Janelli, 2019; Janelli & Lipnevich, in press) that used a multivariate experiment with random assignment to examine the effects of pre-tests and feedback on learners' performance and persistence in a five-week massive open online course (MOOC), and offer practical implications that are related to the study's findings.

## Assessment and MOOCs

Assessment is an integral part of education, discussed and debated by teachers, administrators, parents, policy-makers, and researchers alike. Typically, assessment literature juxtaposes formative and summative assessment. Whereas formative assessment supports learning through feedback, summative assessment measures performance after a unit of instruction (Bull & Stephens, 1999; Gikandi, Morrow, & Davis, 2011). Some approaches fuse the two types of assessment and use the results of summative tests to improve student performance and learning, hence changing the focus of these assessments from summative to formative. Research shows that this formative assessment can positively affect learning outcomes. For example, in a meta-analysis of 250 publications, Black and Wiliam (1998) reported that formative assessment, when done well, can lead to meaningful improvements in learning (with a mean effect size range of .4 to .7). The results of another meta-analysis of formative assessment, conducted by Kingston and Nash (2011), had a median effect size of .25 and a mean effect size of .2. These meta-analyses confirm the findings from countless studies that formative assessment supports learning (Brookhart, 2018). However, all of the reported studies have been conducted in traditional educational settings, and the effects of assessment on learning outcomes for people enrolled in MOOCs has yet to be explicated.

The relation between learning and assessment is complex (Whitelock, 2011), and there are many types of assessment activities that are used in educational settings. One of these is testing. Several researchers have conducted studies designed to help us better understand the varied learning benefits of testing. We know from this research, for example, that testing has positive effects on retention of the material (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). In multiple studies (Carpenter, 2009; Glover, 1989; Karpicke & Roediger, 2008; Richland, Kornell, & Kao, 2009; Roediger & Karpicke, 2006), students who were given a practice test performed better on a post-test than those who were not exposed to the practice test.

Pre-tests, defined as assessments administered at the beginning of instructional units, can be used for instructional placement, such as identifying students who might benefit from gifted and talented programs (Guskey, 2018). Additionally, pre-tests can increase students' awareness of instructional expectations, help students organize content (Hartley & Davies, 1976), enhance memory (Richland et al., 2009) and focus students' attention on specific content (Hartley & Davies, 1976; Richland et al., 2009). At the same time, testing serves another purpose. Research evidence shows that testing can be used for both assessment and learning new material (Koedinger, McLaughlin, & Heffernan, 2010; Richland et al.,

2009). That is, in the process of taking a test the nature of students' knowledge may be altered (Marsh, Roediger, Bjork, & Bjork, 2007). Put simply, tests facilitate learning (Bjork, Storm, & deWistanley, 2010).

Pre- and post-test studies (Bjork et al., 2010) have shown that testing improved learning outcomes even when the tests were administered prior to learning new material. Here, the act of taking a test before a unit of instruction may have helped students to develop the ability to process and retain information that would be learned in the future. Similarly, Pressley and Tanenbaum (1990) found that undergraduates who answered the questions on a pre-test had significant learning gains compared to the control group, in which the pre-test questions were read but not answered. This study supported the idea that it was the active task of answering pre-test questions, and not the passive task of reading pre-test questions, that lead to learning gains.

Scholars have several hypotheses about how and why testing is beneficial. Bjork, Storm, and deWinstanley (2010) suggest that one possible reason learning occurs during the test-taking process is because successfully retrieving the facts on the test modifies and reinforces the way the material is represented in the memory; thus, the very act of retrieval during a test makes the information more easily accessible during future moments of recall. This is called the transfer-appropriate multifactor account (Bjork et al., 2010) or the retrieval hypothesis (Glover, 1989). The more times students successfully recall information, the more likely they are to successfully recall that information in the future.

Another potential explanation for the benefit of testing is called the amount of processing hypothesis. That is, the act of test-taking forces students to spend processing time on specific information. Therefore, any information presented on one test (which represents an opportunity for processing time) should be more easily recalled on subsequent tests (Glover, 1989). These and other hypotheses represent the potential direct effects of test-taking on student learning outcomes.

There are potential indirect effects, as well. For example, frequent testing can encourage distributed practice (Bjork et al., 2010), which has proven to be a highly effective study strategy (Dunlosky et al., 2013). Additionally, test-taking provides students with information (feedback) about their current level of understanding, which can help them identify areas on which they should focus future attention (Smith & Lipnevich, 2018). Finally, and perhaps most simply, tests highlight important information to which students should pay particular attention (Bjork et al., 2010).

In sum, research indicates that testing can yield positive learning outcomes, even if the test questions are not answered correctly, provided that feedback and/or subsequent instruction guides students toward the correct information (Richland et al., 2009). Similarly to assessment in general, studies about the effects of testing have been conducted on samples of students enrolled in traditional educational programs. To our knowledge, at the time of this writing, there was no research examining the effects of pre-tests with varied types of feedback on performance outcomes and persistence for adult students enrolled in MOOCs. Hence, we decided to close this chasm and conduct an investigation exploring these contingencies.

## Our Experimental Study

To examine the effects of pre-tests and feedback on performance and persistence in a five-week massive open online course (MOOC) we conducted an experimental study. The participants were adults from around the world who self-enrolled in the American Museum of Natural History's (AMNH) climate change MOOC, called Our Earth's Future, that was offered on the Coursera platform.

After enrolling in the course, participants were randomly assigned to one of the following conditions: (1) pre-tests with no feedback; (2) pre-tests with basic feedback; (3) pre-tests with elaborate feedback; or (4)

the control group (no pre-test). Participants in the three treatment groups were able to take a pre-test at the start of each of the five course modules to assess their existing knowledge of the evidence for climate change.

The difference among the conditions was as follows. Participants who were randomly assigned to the first treatment group received a pre-test score with no indication of which questions they answered incorrectly. Participants in the second treatment group received a pre-test score that indicated which questions they answered correctly and incorrectly. And participants assigned to the third treatment group received a pre-test score and elaborate feedback for each question they answered incorrectly. Participants in all three treatment groups were also invited to submit module-level post-tests, which were used as an outcome measure. Those enrolled in the control group were only given the post-tests. All of the pre-tests and post-tests were delivered via the Coursera platform as part of the online learning experience. Our outcome variables were student performance on the post-tests and persistence in the course.

As is true of all AMNH MOOC tests, participation was optional, and anyone who chose not to complete the tests still had access to the course content. Additionally, those who wanted to complete the tests without participating in the study were able to receive the pre- and post-tests via e-mail.

Of the 606 participants, 399 met the criteria for inclusion in the final analysis. Data from the following participants were excluded: (1) people younger than 18; (2) those who took the post-tests before the pre-tests; (3) those who took the post-tests less than 20 minutes after taking the pre-tests (an indication that they did not spend much time on the instructional content); (4) those who took the pre-tests but not the corresponding post-tests, and vice versa. The final sample was comprised of 98 participants in the first treatment group; 102 participants in the second treatment group; 96 participants in the third treatment group; and 103 participants in the control group.

Demographic data were collected from two sources: a pre-course survey that was administered by AMNH and a demographic survey that was administered by Coursera. Of the respondents who disclosed their sex, 25 were male and 38 were female. The majority of respondents selected White (75.8%) as their ethnicity. The rest of the respondents identified as Asian (7.6%), Hispanic (4.5%), American Indian or Alaskan Native (1.5%), and Other (6%). The remaining 4.5% declined to answer. Seventeen countries were represented in the survey data. Respondents reported that they live in the United States (42.4%), Canada (18.2%), the United Kingdom (9.1%), France (4.5%), Mexico (4.5%), Portugal (3%), and Switzerland (3%). The remaining respondents reported that they live in ten other countries. Finally, the vast majority of respondents (87.8%) selected that they completed at least a Bachelor's degree. 1.5% of respondents completed high school. 7.6% earned an Associate's degree. 42.4% earned a Bachelor's degree. 24.2% earned a Master's degree. 21.2% earned a professional or doctoral degree. And the remaining 3.1% of respondents had a different level of education or selected "does not apply".

In this chapter we will mostly focus on course persistence, which was measured by the number of modules completed by participants. In a traditional or formal online course, persistence might be measured by participants' progress from module one to module two, from module two to module three, etc. This is not a useful measure of persistence in a MOOC because course participation is highly variable. For example, research has shown that the majority of students who enroll in a MOOC complete the course material out of order (Kalkanis, 2019). Additionally, persistence in MOOCs is measured by Coursera and AMNH in terms of the number of active participants within a given module, without regard for the order in which the modules are completed. For example, in the Our Earth's Future sample, 44 participants (11%) chose not to begin the course with module one. Their level of persistence in the course should not be discounted simply because they did not begin the course with the first module. For these reasons, we indexed course persistence not by the linear or sequential completion of each module, but rather by the total number of modules completed by each participant. Related to course persistence, we

also examined course completion, operationalized as students' submission of a post-test in all five modules. Hence, for the purposes of our study course completion is the ultimate course persistence. Please refer to Janelli (2019) and Janelli and Lipnevich (in press) for complete details about the study, including a thorough description of the differences in performance across the four conditions; here, the authors focus on the results concerning learners' persistence in the course.

In general, the mean number of modules completed by all participants (N = 399) was 3.01 (SD = 1.70). Interestingly, the mean number of modules completed by the first treatment group (pre-test no feedback) was 2.60 (SD = 1.65); 3.03 (SD = 1.66) by the second treatment group (pre-test basic feedback); and 2.94 (SD = 1.67) by the third treatment group (pre-test elaborate feedback). To our surprise, the group that demonstrated the highest persistence was the control group, with an average of 3.44 (SD = 1.74) completed modules. See Table 1 for a summary of the course persistence data.

*Table 1. Course persistence: Mean number of modules completed*

| Condition | N | Mean | SD |
|---|---|---|---|
| Pre-test no feedback | 98 | 2.60 | 1.65 |
| Pre-test basic feedback | 102 | 3.03 | 1.66 |
| Pre-test elaborate feedback | 96 | 2.94 | 1.67 |
| Control | 103 | 3.44 | 1.74 |
| Total | 399 | 3.01 | 1.70 |

To fully explore the question of persistence and our somewhat puzzling findings, we conducted an analysis to answer the following question: Were there group differences, by treatment, in the level of course persistence as indicated by the number of modules that were completed? The results of the ordinal logistic regression analysis confirmed that learners in the control group were more likely to persist through the course than those in the treatment groups. In other words, pre-tests, regardless of feedback type, significantly and negatively affected course persistence.

Related to persistence, we also examined differences in course completion and the results of the analyses for this outcome were no less surprising. In the first treatment group (pre-test no feedback), 22 participants (22.4%) completed the course. In the second treatment group (pre-test basic feedback), 34 participants (33.3%) completed the course. And in the third treatment group (pre-test elaborate feedback), 30 participants (31.3%) completed the course. Once again, the control group exceeded our expectations with 51 participants (49.5%) completing the course.

We explored these differences in the course completion variable with a logistic regression analysis. The results revealed that learners in the three experimental conditions were significantly less likely than the control group to complete the course. See Figure 1 for the chart of course completion by each of the four conditions.

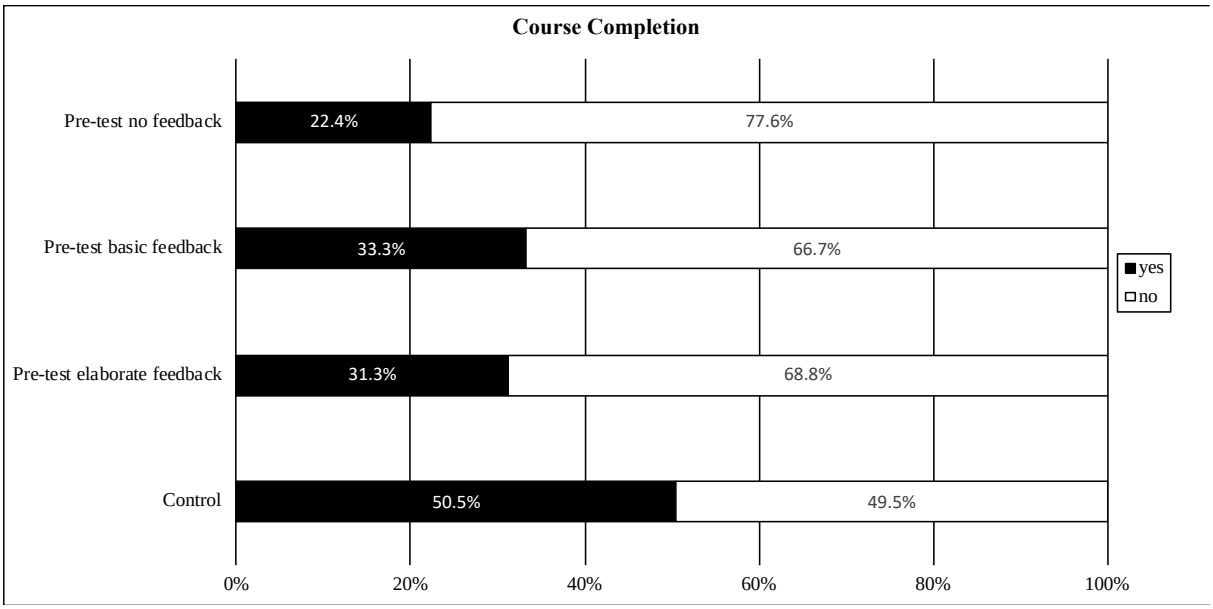

*Figure 1. Course completion by condition (N = 399)*

In a previous study (Janelli, 2019; Janelli & Lipnevich, in press), we also examined the subset of course completers to see if pre-tests and corresponding feedback resulted in better performance on the post-tests. Indeed, among learners who completed all five modules, those assigned to the three pre-test conditions showed better results on post-tests than those in the control group. Thus, while pre-tests negatively affected persistence among the entire sample, they positively affected post-test scores among the sub-sample of course completers.

In summary, this research built upon existing assessment and feedback literature by providing pre-tests and feedback to students prior to a unit of instruction. A post-test measured learning gains. In this way, we attempted to study whether or not the pre-test findings observed with traditional students in face-to-face classrooms are also present among non-traditional students in self-guided online courses. We found that: (1) among all users in a MOOC, pre-tests and feedback did not affect learning outcomes; (2) the presence of pre-tests significantly and negatively affected course persistence and completion, deterring some participants from progressing through the course; (3) among those who did persist and complete the course, however, those who took pre-tests achieved higher learning outcomes than those who did not; and (4) among those who took pre-tests, there was a positive, cumulative effect of persistence (module completion) on performance on post-tests (Janelli, 2019; Janelli & Lipnevich, in press).These findings represent a new contribution to the literature on assessment and feedback, expanding the field to include adult participants from around the world who enrolled in a self-paced, not-for-credit online science course. The results pave the way for future research in this area with this population and have a direct practical application for online course developers, offering them information to help improve student learning outcomes and engagement.

## Explanations for the Experiment's Findings

Based on the literature related to testing and feedback, we expected that pre-tests and feedback would affect performance, persistence, and course completion in the present study. This expectation was reinforced by a MOOC study that was conducted in 2015. In an analysis of student ratings of MOOCs on a course review website (www.coursetalk.com), researchers found that students reported that they appreciated immediate feedback on automated tests so that they could identify gaps in what they had learned. Furthermore, when feedback on tests was provided, students reported that they preferred specific feedback that indicated why their answer was wrong and which answer was correct (Floratos, Guasch, &

Espasa, 2015). However, these anecdotal preferences for feedback on tests were not supported in the current study; we found no quantitative evidence demonstrating that feedback on multiple-choice tests lead to higher learning outcomes. Despite abundant evidence in the literature about the positive effects of assessment feedback, findings from this work suggest that, within MOOCs, pre-test feedback has no effect on learning outcomes. Possible explanations for this include: limited prior knowledge; structural elements of the tests; participants' receptivity and responses to feedback; and the inability to generalize feedback findings from traditional student populations to MOOC student populations.

Let's briefly look at these explanations. With regard to students' limited prior knowledge, several authors note that the effectiveness of feedback can sometimes be dependent upon students' existing knowledge base (Hattie & Timperley, 2007; Narciss & Huth, 2002) and their ability to connect the feedback they receive to what they already know and what they are being taught (Hattie & Timperley, 2007). Without sufficient prior knowledge, making these connections may not be possible.

The structure of the tests provides a second possible explanation for the ineffectiveness of feedback. This may have had an effect in one of three ways. First, the pre-test questions may have been too dissimilar from the post-test questions. This finding was observed in a study of the effects of different types of computer-based feedback on learning outcomes with high school science students. In that experiment, researchers found that feedback was more effective when the questions that appeared during instruction were identical to the questions that appeared after instruction. As the similarity between the instructional tests and post-tests decreased, so too did the effects of feedback (Clariana, Ross, & Morrison, 1991). A similar finding was observed in a study of feedback in multiple-choice tests conducted by Butler and Roediger (2008), further supporting the idea that feedback is more effective when pre- and post-test questions are identical. The post-test questions used in the current study were different from the pre-test questions, possibly affecting feedback-related learning outcomes.

The second structural element of the tests that may have affected the usefulness of feedback is that none of the feedback groups received the correct response to the pre-test questions. In one study about this topic, researchers examined whether or not feedback could be used to enhance the positive effects of multiple-choice tests and diminish the negative effects of multiple-choice tests. They concluded that the most important piece of feedback provided to students after a multiple-choice test is not verification feedback or elaborate feedback; rather, the most important feedback to provide is the correct answer, which gives students an opportunity to encode the correct response for future retrieval attempts (Butler & Roediger, 2008).

In the present study, participants in the pre-test no feedback group received a test score without an indication of which questions were answered correctly/incorrectly. Participants in the pre-test basic feedback group received a test score with an indication of which questions were answered correctly/incorrectly. And participants in the pre-test elaborate feedback group received a test score with an indication of which questions were answered correctly/incorrectly along with elaborate feedback explaining why their incorrect answers were wrong. None of the treatment groups received feedback that indicated which answer was correct. This is the second component of the test structure that may have limited the effectiveness of the feedback.

The third structural element of the tests that may have affected the usefulness of feedback is time between tests. It is possible that too much time may have elapsed between when participants took the pre-tests and when they took the post-tests. Unfortunately, there is no way to impose minimum or maximum time-between-tests upon participants in a MOOC. However, the Coursera platform itself could be used to track and analyze test submission timestamp data for a future study. Analyzing additional data such as time-between-tests is one of the benefits of digital assessments (Parshall, 1995) and would help to shed light on our understanding of the effectiveness of feedback types in automated assessments for MOOC students.

We can look to participants' receptivity and responses to feedback as a third possible explanation for the ineffectiveness of pre-test feedback in the present study. We know that context matters when delivering feedback, and student receptivity is a critical context to consider (Brookhart, 2018; Lipnevich, Berg, & Smith, 2017). Individual student factors that affect receptivity to feedback include ability, history with feedback, positive or negative dispositions toward feedback, and feedback preferences (Lipnevich et al., 2017). Participants with low receptivity to feedback in the present study may not have spent enough time reviewing feedback, or they may have ignored it completely. Reading ability may have negatively affected receptivity to feedback and participants' dispositions toward feedback may have affected their motivation to utilize it.

One last possible explanation for our findings in the present study is that results obtained in samples with traditional students simply do not generalize to this non-traditional population of learners. Many scholars and educators posit that the MOOC experience is fundamentally different from other kinds of learning and therefore requires special research considerations. Any one of these factors – or a combination of them – may have contributed to the findings in the present study.

## Persistence and Completion: Taking a Closer Look

We learned from this study that pre-tests significantly affected persistence and course completion, but not in the way that we anticipated. And we have offered several possible explanations for the ineffectiveness of feedback on post-test scores. But what of the unexpected findings related to persistence and completion? Results from the analyses of persistence indicated that participants who received pre-tests and feedback were less likely than participants in the control group to complete additional course modules. Additionally, those in the three treatment groups were more likely than those in the control group to drop out of the course. Course persistence is closely related to course completion. As exposure to pre-tests significantly and negatively affected persistence, pre-tests also significantly and negatively affected course completion. Analyses of the effects of condition on course completion indicated that participants in the three treatment groups were significantly less likely to complete the course than participants in the control group. Thus, exposure to pre-tests had a negative effect on both persistence and completion.

These findings had not been previously observed in the literature. One possible reason is that the majority of traditional students who participate in educational research studies do not often drop out of a course mid-semester or mid-school year. As such, there is no reason to investigate the effect of pre-tests on attrition in individual face-to-face classes because that particular phenomenon does not exist among that population.

Another possible reason for the absence of this finding in the related literature is that MOOC research is still relatively new (Pappano, 2012). Given the limited number of MOOC studies that exist, compared to the vast number of general education studies, it is not surprising that this issue has not yet been studied.

Interestingly, the original research study found that, among those in the three treatment groups, there was a positive, cumulative effect of course persistence (module completion) on post-test composite scores. Mean post-test composite scores increased over time, with participants who completed the course scoring nearly nine points higher than their peers who only completed one module. With an effect size of .54, this finding suggests that there is a benefit to taking pre-tests throughout a course, prior to the start of each instructional unit (Janelli, 2019; Janelli & Lipnevich, in press). This is consistent with other findings in the literature. We know, for example, that frequent testing is a form of distributed practice, and that distributed practice is one of the most effective study habits in which students can engage (Dunlosky et al., 2013). It is not surprising, then, that those who persisted and took pre-tests throughout the course

experienced a positive cumulative effect of that distributed practice. This effect was not observed among the control group.

Though MOOC research is still in its infancy, we can look to this educational domain to help explain our findings. For example, researchers recently conducted a study of MOOCs offered by the University of Texas at Austin and hosted on the edX platform. Their goal was to try to understand MOOC persistence and engagement relative to individual student goals at the time of enrollment. Using pre-course surveys and course activity data, they found that students enrolled in STEM courses had lower engagement because they left the courses after finding the information they needed, and they often did not intend to complete the courses at all. This finding was not observed in non-STEM courses (Williams et al., 2018). As Our Earth's Future is a STEM course about climate science, this effect may have been a factor in the attrition of many and the engagement of few.

Another MOOC-related factor that may have affected the present study's outcomes is the self-guided nature of the course. In Our Earth's Future (and all other AMNH MOOCs, and many other non-degree MOOCs), the presence of the instructor is limited to her appearance in course lecture videos. The instructor does not greet students or answer questions in the discussion forums, provide individual feedback on students' progress, or congratulate them on their achievements. This is typical of MOOCs, a consequence of being too "massive" to provide instructor presence in an individual and traditional way.

Unfortunately, this lack of interpersonal connectivity in a MOOC may affect students' engagement with the material and persistence in the course. In a study about student engagement in MOOCs, Jung & Lee (2018) found a relation between instructor presence and persistence: Attrition increased when there was limited instructor presence in a course, an effect that was also found in a study by Hone and El Said (2016). Similar findings were also observed in a recent study that identified relations among student engagement, persistence, course completion, and instructor presence (Gregori, Zhang, Galván-Fernández, & Fernández-Navarro, 2018). It seems that in MOOCs, like in traditional formal education settings, the teacher matters. The more present a teacher is, the more active the students will be. However, in a course with many thousands of students, this poses a unique challenge. For some institutional MOOC developers with significant financial resources, paying for a small army of instructional staff to provide support to students is possible. For others, however, hiring enough instructional staff to monitor MOOCs and provide personalized support to students is cost-prohibitive. Unfortunately, creating MOOCs that are purely self-guided is often the price of doing business in this space. The benefit of scalability comes at the cost of instructor presence. This lack of instructor presence in Our Earth's Future may have affected attrition, engagement, persistence, and completion in the present study.

Our findings differ from some reported in the literature. For example, Evans, Baker, and Dee (2015) found that completing a pre-course survey was among the biggest predictors of course completion, with students who completed the survey three times more likely to complete the MOOC than those who did not complete the survey. Moreover, these findings were observed in a STEM MOOC. However, we did not observe this finding in the current study. This underscores the fact that even within the domain of MOOC research, samples and courses are varied and inconsistencies abound.

Our results, along with the results of studies herein reported, present practitioners with a unique and specific instructional design challenge. Do we design informal online courses without pre-tests in order to minimize attrition? Or do we include pre-tests in informal online courses in order to maximize learning outcomes for course completers? In other words, do we privilege the learning of the minority over the persistence of the majority? We posit that this is a false choice. To consider this an either/or challenge is to forget about the initial promise of MOOCs as disruptors and innovators of online learning. If we recall the potential of MOOCs when they rose to popularity in 2012, then several solutions to this challenge become more readily apparent.

## Opportunities for Instructional Designers

One way to maximize the benefits of the study's contradictory findings is to consider separate design paths for a given MOOC: one version of a course with no pre-tests for those who do not intend to complete the course, and another version of the course with pre-tests for those who do intend to complete the course. This would maximize persistence for people who do not want to take pre-tests and maximize learning outcomes for people who do.

Another possibility is to foster students' extrinsic motivation to engage with the course materials by applying gamification techniques to the MOOC experience. This could be achieved by awarding digital badges for completing tests, or by implementing individual test leaderboards or a course-level leaderboard (Gené, Núñez, & Blanco, 2014). Offering micro-credentials for courses might also support student motivation.

Still another way to encourage engagement with the pre-tests is to raise the stakes by incorporating the pre-tests into the overall course grade. In Our Earth's Future, pre-tests were not factored into the course grade. If they had contributed to just a small percentage of the final grade, more students might have completed them. Though these strategies might incentivize more people to progress through more of the material, they would not necessarily lead to less attrition.

The last possible instructional design modification is larger in scope, and challenging to implement. Because the MOOC population and engagement with course material are highly variable (Kalkanis, 2019), findings from this and other MOOC-related research (Koedinger, McLaughlin, Kim, Jia, & Bier, 2015) make a compelling case for creating a more interactive and less prescriptive MOOC experience for students. Indeed, Coursera CEO Jeff Maggioncalda recently acknowledged that "different learners need different solutions" (Maggioncalda, 2019). Embedding digital activities into MOOCs is one way to accomplish this objective. Another way to do this is through adaptive technology.

Adaptive learning, or the use of intelligent technology to create personalized learning pathways for individual students, could be a wonderful solution to the challenges presented by MOOCs while also pushing MOOC platforms to deliver on their early promise of innovation in teaching, learning, and educational technology. It's easy to imagine a choose-your-own-adventure format of MOOC participation. After completing a pre-course questionnaire, a custom version of a course could be immediately created and presented to newly enrolled students based upon their learning preferences (which already dictate a MOOC learner's engagement and progress in a course). Customizations could include: discrete sub-topics, content types (essays vs. videos vs. audio files), assessment types (multiple-choice vs. peer-reviewed), and forums (if any). At the very least, there is potential for adaptive assessments in which questions vary in difficulty and are presented to students based upon their ability, prior knowledge, and performance. This custom approach to informal online instruction would support the learning of people in MOOCs regardless of their intention to complete the course. Right now, MOOC students are forced to operate within the often ill-fitting constraints of the MOOC framework. Rather than force the framework on the student, we need to change the framework to fit the learner. Radically changing MOOC development to incorporate custom and adaptive components may lead to the equity and achievement outcomes that have long been the promise of this technology.

MOOCs allow students to order their learning materials in a manner similar to that of a restaurant buffet, which is very different from the prix fixe menu of traditional courses. Therefore, perhaps it is not our job to pre-select the prix fixe options for all learners, but rather to provide a robust buffet in which all learners can find exactly what they want. How do we support those already committed to deep learning without ignoring those who are simply curious about a topic? How do we design learning pathways for every learner, regardless of their intention to persist and complete a course? How do we fund the development

of instructional models that meet the needs of all online learners? These questions certainly lend themselves to a variety of possibilities for future research and online course development.


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## KEY TERMS AND DEFINITIONS

**Assessment:** Evaluation of performance and learning.

**Coursera:** One of the leading providers of Massive Open Online Courses. The Coursera platform includes an administrative interface that allows researchers to design and conduct multivariate experiments with random assignment.

**Educational Technology:** Media that is researched and iteratively designed and developed to facilitate teaching and learning.

**Feedback:** Any information about a performance that learners can use to improve performance or learning. Feedback might come from a teacher, a peer, the learner observing the results of his or her efforts, or the task itself. It may include information on where the learner is, where the learner is going, or what steps should be taken and strategies employed to get there .

**Informal Online Learning:** Self-guided digital pursuit of knowledge, information, and community that happens outside formal educational programs such as degree-based programs or structured online professional development modules.

**Massive Open Online Courses (MOOCs):** Online courses offered by professors from universities around the world and hosted on platforms such as Coursera, edX, and FutureLearn; they range from being completely free with no course credit to being paid-for experiences that culminate in certificates, undergraduate or graduate credits, micro-degrees, or degrees.

**Pre-tests:** Tests that are administered prior to instruction for one of several reasons, such as formative assessment, to establish a baseline against which learning can be measured, as instructional materials, for student placement, etc.