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Learning During COVID-19

Engagement and Attainment in an Introductory Biology MOOC

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During the COVID-19 pandemic, learning in higher education and beyond shifted *en masse* to online formats, with the short- and long-term consequences for Massive Open Online Course (MOOC) platforms, learners, and creators still under evaluation. In this paper, we sought to determine whether the COVID-19 pandemic and this shift to online learning led to increased learner engagement and attainment in a single introductory biology MOOC through evaluating enrollment, proportional and individual engagement, and verification and performance data. As this MOOC regularly operates each year, we compared these data collected from two course runs during the pandemic to three pre-pandemic runs. During the first pandemic run, the number and rate of learners enrolling in the course doubled when compared to prior runs, while the second pandemic run indicated a gradual return to pre-pandemic enrollment. Due to higher enrollment, more learners viewed videos, attempted problems, and posted to the discussion forums during the pandemic. Participants engaged with forums in higher proportions in both pandemic runs, but the proportion of participants who viewed videos decreased in the second pandemic run relative to the prior runs. A higher percentage of learners chose to pursue a certificate via the verified track in each pandemic run, though a smaller proportion earned certification in the second pandemic run. During the pandemic, more enrolled learners did not necessarily correlate to greater engagement by all metrics. While verified-track learner performance varied widely during each run, the effects of the pandemic were not uniform for learners, much like in other aspects of life. As such, individual engagement trends in the first pandemic run largely resemble pre-pandemic metrics but with more learners overall, while engagement trends in the second pandemic run are less like pre-pandemic metrics, hinting at learner "fatigue". This study serves to highlight the life-long learning opportunity that MOOCs offer is even more critical when traditional education modes are disrupted and more people are at home or unemployed. This work indicates that this boom in MOOC participation

may not remain at a high level for the longer term in any one course, but overall, the number of MOOCs, programs, and learners continues to grow.

1 Introduction

Universities and companies offer massive open online courses, or MOOCs, through a platform provider. MOOCs branch across many subject areas of varying expertise levels, and platforms offer thousands of MOOCs that increase access and affordability of education to learners worldwide. By lessening the barriers of entry into traditional higher education, the diversity of the virtual, international MOOC "classroom" is greater than what an in-person classroom typically achieves, and thus learner motivations, personal backgrounds, and learning environments are also greatly varied [1].

However, the COVID-19 pandemic shifted schools from pre-K to graduate level *en masse* to virtual formats, with many countries running schools primarily online by the end of March 2020 [15, 6]. While serving an important role before, MOOCs became exceptionally critical in this time of upset, in part due to their easy access for a variety of new learners or the sudden need for online teaching resources. In addition, unprecedented employment loss occurred during 2020, particularly in the Americas, for women, and for young workers [8]. Rising unemployment likely gave some learners the time and need to gain or enhance skills for future employment. Many MOOC platforms cited increased website traffic and offered discounted or free services to meet these learners' concerns [17, 5, 4]. Indeed, MOOC providers had exceptional growth during 2020, with 30 new MOOC-based degrees and over 60 million new learners [17].

Prior analyses of the pandemic's effect on learners largely focused on the great increase in enrolled learners and shifting learner interests in MOOC topics, though one study investigated how learner experiences in the pandemic impacted their MOOC engagement [17, 16]. These authors cited increases in the number of new learners and overall enrolled learners, but did not address changes in learner participation, engagement, or achievement.

We sought to determine whether the COVID-19 pandemic increased learner engagement and attainment in a single introductory biology course through the following measures:

1. Enrollment and demographics (country and ".edu" participants).

2. Proportion of learners engaged with videos, problems, and forums.

3. Number of individual engagement events with videos, problems, and forums.

4. Verification and performance.

Given the increases in MOOC provider website traffic, we hypothesized that learner enrollment and engagement in this biology MOOC increased during the COVID-19 pandemic. Despite expecting more learners, we hypothesized that these learners would not score or pass the course at higher proportions as prior to the pandemic.

This college-level introductory biology course has been available on a MOOC platform since 2013. Learners can choose to enroll in the free auditor track or pay for the verified track. The verified track gives access to additional course content, namely a comprehensive competency exam required to earn a passing score for certification. The course materials are mostly available for self-paced learning within a defined start and end date, but the competency exam is only available during the final week of the course run. To address our research questions, we evaluated data from three pre-pandemic runs of the course and two runs during the pandemic.

2 Body of Paper

2.1 Materials and Methods

The enrollment and individual course activity data came from five runs of the course in this study: three pre-pandemic runs of April 2019, July 2019, November 2019 and two pandemic runs of March 2020 and July 2020. These runs follow the naming convention of the month and year (March 2020) from the course start date (March 3, 2020). The course ran with no overlapping dates between runs and no differences in the organization of the course except for an extra week of time during the pandemic runs. Learners received course staff emails with similar frequency and content in all course runs.

We defined classification labels to categorize course registrants. Learners enrolled in the course. If enrolled in the auditor track, we referred to those learners as auditor-track; if enrolled in the paid verified track, we referred to those learners as verified-track. As previously defined, we used the term participants for learners who viewed the course at least once [7]. As such, being a learner was a prerequisite to being a participant which was a prerequisite to being engaged. Engaged participants performed one of the following engagement metrics:

1. Viewed a video: participant clicked the play button on a video.

2. Attempted a problem: participant submitted an answer to a problem.

3. Posted on the forum: participant posted/commented on the forum. Posts start a new thread, responses are answers to the original post, and comments are answers to a response.

4. Attempted the competency exam: verified-track participant who scored higher than zero.

We calculated learner enrollment, participation, engagement, and attainment using BigQuery pre-computed files from clickstream data. These files contained learner IDs, demographic and performance data, and engagement information such as video views, problem attempts, and forum posts. We excluded non-learners, staff and community teaching assistants, and considered only engagement within the start and end dates of each run. In many cases, we judged engagement as a percentage of participants to account for large differences in enrolled learners. We processed data, performed calculations, and plotted results with Python *pandas* in Jupyter Notebook and Tableau Desktop [14, 10]. We determined significance of data using a student's t-test where applicable.

2.2 Results

2.2.1 Enrollment and Demographics

Since the pandemic affected different countries in different ways, we first determined participants' location according to their profile. For all course runs, the most common participant location was the United States followed by India and the United Kingdom. Cumulatively, these three countries accounted for approximately 40% of participants with an additional 10% of participants having no location reported. Participants represented more than 160 countries. The proportions of participants from the other countries remained mostly constant between all runs, with each other country contributing less than 4% of participants.

To address our first research question more, we analyzed enrollment change over time by enrollment count, the total number of learners who enrolled and remained enrolled in the course for three pre-pandemic runs (April 2019, July 2019, and November 2019) and two pandemic runs (March 2020 and July 2020) of this course. Considering the enrollment count by date (Figure 1), the March 2020 run peaked at nearly 15,000 learners, and the July 2020 run peaked at nearly 12,000 learners, much higher values than the pre-pandemic mean peak enrollment count of 6,811.

When evaluating enrollment over time, the enrollment count for the March 2020 run increased at almost triple the rate of the three pre-pandemic runs. However,

during the early days of the March 2020 enrollment metrics appeared particularly similar to the enrollment metrics in the April 2019 run, both in rate and in count, with enrollment rate increasing sharply around March 15, 2020. In contrast, the July 2020 run began with more than twice as many learners already enrolled by the first day of the course but continued with half the enrollment rate of the March 2020 course run rate.
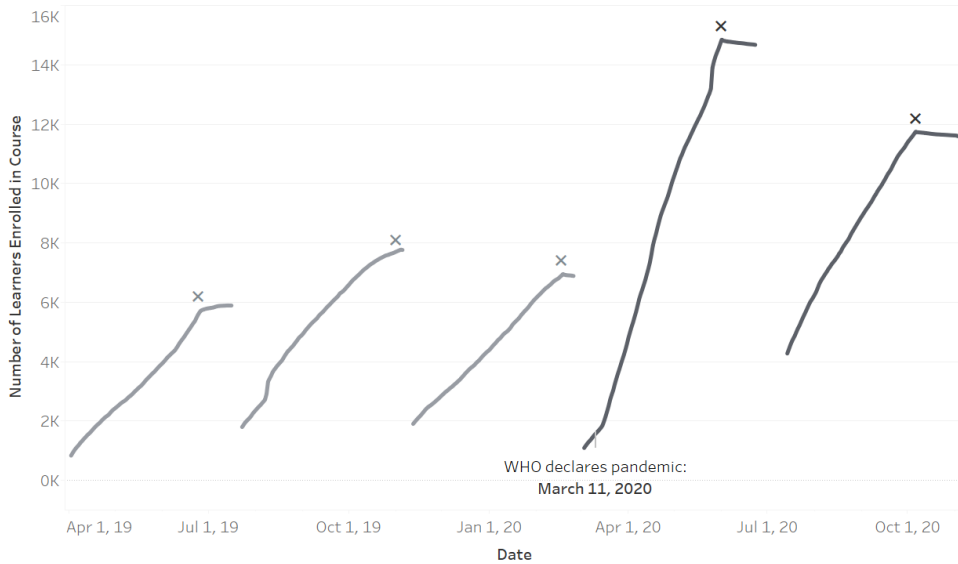

Figure 1: Enrollment trends for five course runs. Enrollment count of learners by date for the three pre-pandemic runs (gray) as well as the two pandemic runs (black). Important global and course run-specific dates are noted. Symbols ($\times$) indicate the enrollment closing date for each run: June 26, 2019 for April 2019; November 3, 2019 for July 2019; February 18, 2020 for November 2019; June 2, 2020 for March 2020; and October 6, 2020 for July 2020.

2.2.2 Proportion of Engaged Learners

The pandemic runs of this MOOC had a significantly increased number of learners enrolled, but did more learners engage with the course? We first calculated the percent of learners who classified as participants (accessed the course at least once over the course of the run) in Table 1. We found the percent of participating learners peaked in the first pandemic run, March 2020, at 75.3% and dipped to a low of

65.4% in the second pandemic run, July 2020, with pre-pandemic percentages between the two pandemic runs. Despite an approximately 10% decline between the March 2020 and the July 2020 runs, both pandemic runs still have the highest count of participants due to much higher enrollment count.

Table 1: Percentage and count of participating learners

Run	Percent of Participating Learners of Registered	Count of Participants
April 2019	68.3%	4,222
July 2019	68.3%	5,619
November 2019	71.1%	5,184
March 2020	75.3%	11,679
July 2020	65.4%	8,097

To better understand participant engagement, we calculated the percent of participants who performed an engagement action at least once in the course run: viewed a video, attempted a problem, and posted to a forum (Figure 2). We selected these actions to represent a range of engagement efforts from more passive viewing a video to more active attempting an assessment or posting to a forum that are associated with learning [11]. We found the proportion of participants who viewed at least one video decreased in the July 2020 run to 53% from a mean of 64% in prior runs. However, the percent of participants who attempted at least one problem in the assessments remained consistent between 45% and 50% across the five runs of this course. In contrast, we found 4.4% of the March 2020 participants and 4.5% of the July 2020 participants engaged through forum posting. This was 1.4 to 3.3 times higher than pre-pandemic proportions of forum posting.

2.2.3 Individual Engagement

Based on these differences in proportions of engaged participants, we investigated our third research question: did learners show increased individual engagement with videos, problems, and the forum during the pandemic runs? We considered only engaged participants for each metric, excluding learners and participants that did not perform the specific engagement action once. For each metric, we split our engaged participants into auditor-track participants, verified-track participants who did not earn certification, and certified participants.

First, we analyzed the number of unique videos viewed by video-engaged participants (Figure 3). Trends of video viewing differed between learner subcategories,
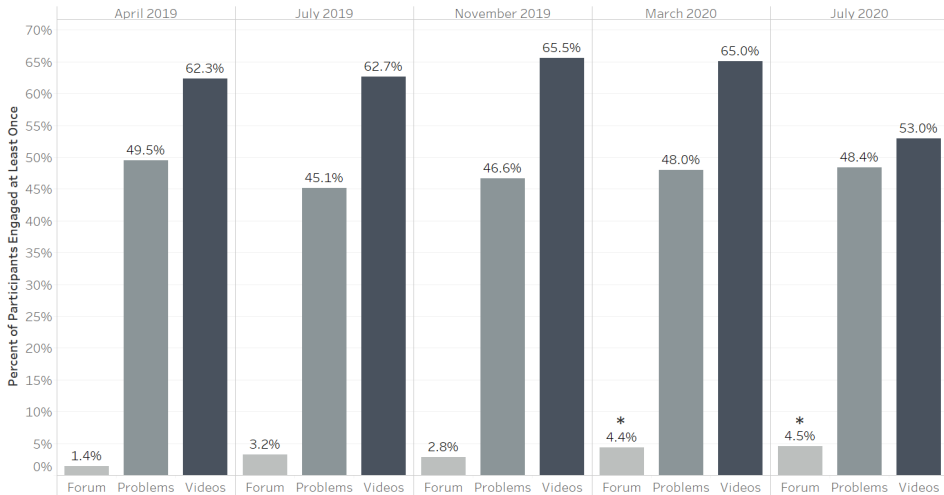
Figure 2: Percentage of engaged participants. The percentage of participants who engaged by posting to a forum (left bar in each block), attempting a problem (middle bar), or viewing a video (right bar) at least once during the course run. Asterisk (*) indicates a significant difference (p = 0.036) between pre-pandemic and pandemic forum engagement proportions.

with auditor-track participants viewing the fewest unique videos and certified learners viewing the most unique videos as we hypothesized. However, video viewing varied widely among auditor- and verified-track participants. Auditor-track participants not aiming to earn certification still viewed all available videos for the course. The median and range of unique video views remained consistent for auditor-track participants across all five runs. During the March 2020 run, certified participants viewed far more unique videos than during the pre-pandemic runs. In contrast, both verified-track and certified participants viewed far fewer unique videos during the July 2020 run than all prior runs. The July 2020 certified participants in particular had a far lower median and third quartile and greater range than the prior runs.

For each video-engaged participant, we calculated a play-per-video ratio by dividing the cumulative number of video play events by the number of unique videos viewed for every individual, a metric of interest as deeper video engagement. Pre-pandemic video-engaged participants had similar play-per-video ratios within their auditor-track, verified-track, or certified status regardless of run (Figure 4). During the March 2020 run, the median and range of play-per-video ratios
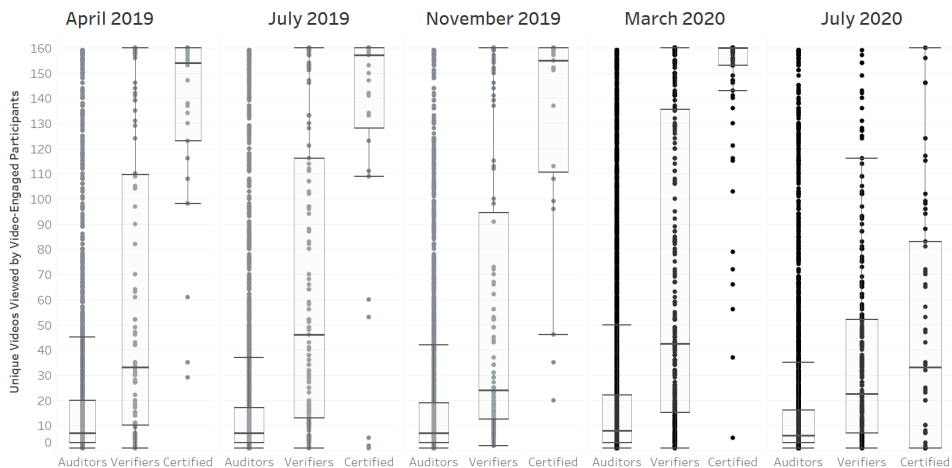
Figure 3: Engagement by number of unique videos viewed. Boxplots of number of unique videos viewed by auditor-track (left boxplot), verified-track without earning certification (middle boxplot), and certified (right boxplot) participants for three pre-pandemic (gray) and two pandemic (black) runs of the course.

increased for all subcategories of video-engaged participants. Interestingly, while video-engaged participants viewed fewer unique videos during the July 2020 run, they also had a higher median and range of play-per-video ratios than prior course runs for both auditor- and verified-track participants.

Similar to our percentage of problem-engaged participants results in Figure 2, we also found that the number of unique problems attempted by problem-engaged participants (Figure 5) remained similar between the five course runs, with auditor-track participants attempting the fewest number of unique problems and certified participants attempting the most.

To further explore the metrics of problem-engaged participants over time, we compared the normalized problem attempts per day, calculated as the total number of problem attempts per day divided by total count of problem-engaged participants in each run (Figure 6). The high peaks at the end of each run indicate studying and engagement with the competency exam for verified participants, though the April 2019 and July 2020 runs also had early peaks of activity. We found that the three pre-pandemic runs and the July 2020 run showed similar participant activity, with a median of normalized problem attempts per day of approximately 0.29. For the March 2020 run, the median was 0.40, an increase of nearly 38% and most evident in the months of April and May in 2020.
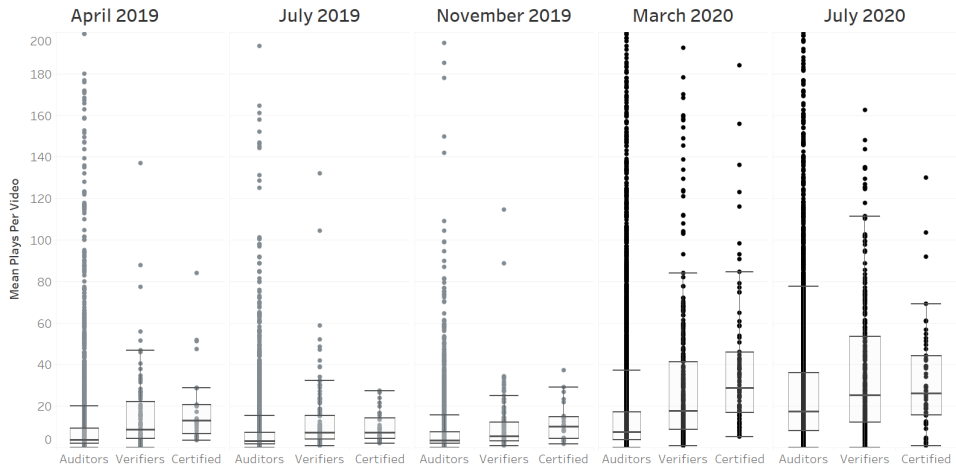
Figure 4: Engagement by video play-events. Boxplots of play events per unique videos viewed by auditor-track (left boxplot), verified-track without earning certification (middle boxplot), and certified (right boxplot) participants for three pre-pandemic (gray) and two pandemic (black) runs of the course.
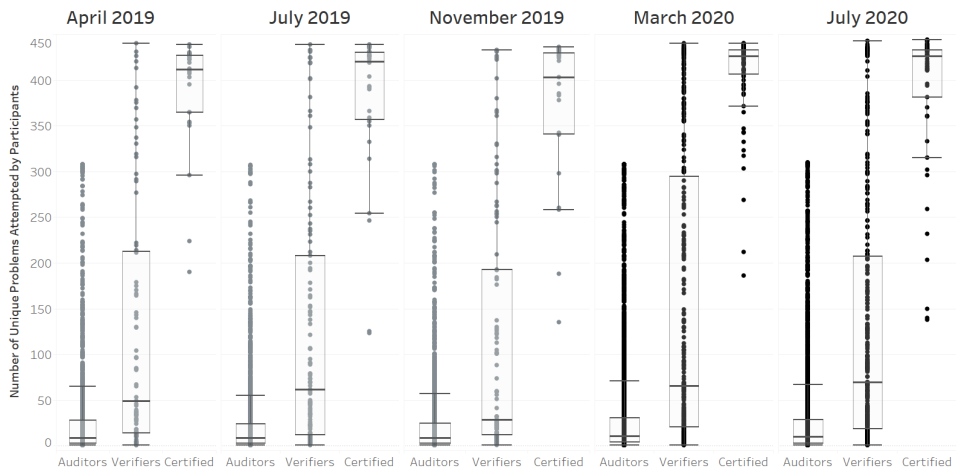

Figure 5: Engagement by number of unique problems attempted. Boxplots of number of unique problems attempted by auditor-track (left boxplot), verified-track without earning certification (middle boxplot), and certified (right boxplot) participants for three pre-pandemic (gray) and two pandemic (black) runs of the course.
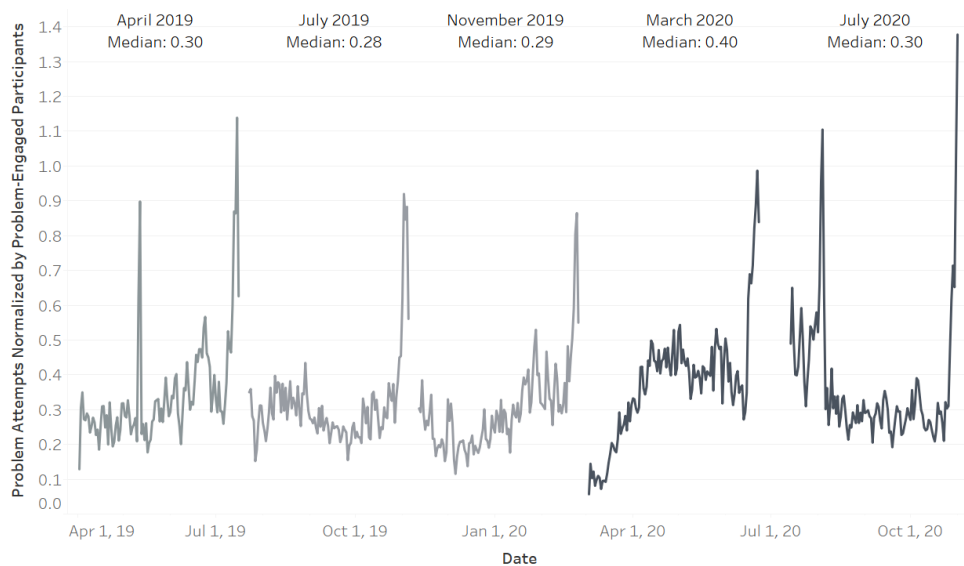
Figure 6: Problem attempts per problem-engaged participant by date. Number of problem attempts per day normalized by total number of problem-engaged participants in each course run. Normalized problem attempts plotted by date for three pre-pandemic runs (gray) and two pandemic runs (black).

In the analysis of the number of forum posts per forum-engaged participant, we found little difference between pre-pandemic and pandemic runs of the course for auditor- and verified-track participants (Figure 7) despite the earlier results (Figure 2). Unlike unique videos viewed (Figure 3) and unique problems attempted (Figure 5), certified participants sometimes, but do not always, make more forum posts than other subcategories [13]. While the majority of forum-engaged participants posted to forums between one and three times, a greater number of forum-engaged participants have posted more times to the forum during the pandemic runs; this is most evident among auditors.

2.2.4 Verification and Performance

We compared the verification and certification trends of participants across course runs. By choosing verified-track, learners indicate an intention to complete most or all of the course content (or at least maintain long-term course access) and, as prior figures have shown, tend to "follow through" on this intention by engaging more with course content. However, as intention does not always lead to successful
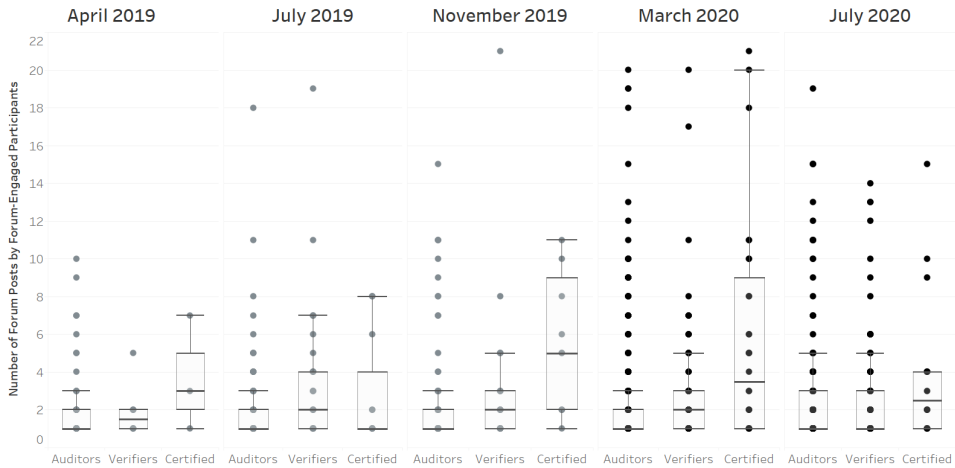
Figure 7: Engagement by number of forum posts. Boxplots of number of forum posts made by auditor-track (left boxplot), verified-track without earning certification (middle boxplot), and certified (right boxplot) participants for three pre-pandemic (gray) and two pandemic (black) runs of the course.

outcomes, we also investigated the final scores and achievement of certification for these verified-track learners.

First, we calculated the percent of verified-track participants out of all participants in each course run (Figure 8 A). The verification percentage during March 2020 was 3.8%, 0.8% higher than the pre-pandemic mean, a 30% change. Since the pandemic runs had so many additional learners, this increase in percentage translated to the March 2020 run having the same count of verified-track participants as the three pre-pandemic runs combined. Additionally, the July 2020 run enrolled nearly as many verified-track participants as the March 2020 run. Due to a lower peak enrollment count during the July 2020 run – though still higher than pre-pandemic runs – the percentage of verified-track participants during the July 2020 run reached 5.2%. This is 2.3% higher than the pre-pandemic mean percentage, a nearly 80% change in verification percentage.

We next investigated the certification percentages among verified-track participants. In this course, participants who have paid for the verified track and have earned a score of 80% or higher on the cumulative competency exam, administered in the final week of the run, earned a certificate (Figure 8 B). We found the certification percentage to decrease in consecutive runs pre-pandemic. The March 2020 run "reversed course" and returned to the pre-pandemic mean of 18.4%, though

it did not surpass the peak certification percentage of 21.5% during April 2019. In contrast, despite the much higher proportion of verified-track participants, the July 2020 run showed the lowest certification percentage of 12.5%. As before, the count of certified individuals during the pandemic runs were much higher than pre-pandemic runs due to far higher enrollment counts.

By including all verified-track participants in the calculation of percent certified, we captured verified-track participants who did not engage with the competency exam (Figure 8 (B)). As such, the percent of verified participants passing is low, as a high proportion of verified participants (approximately 50%) did not attempt the competency exam. However, when we excluded participants with a score of zero and included only at those who engaged with the competency exam, we found certification percentages to be much higher, approximately 40% (Figure 8 (C)). During the July 2020 run, only one-third of exam-engaged verified-track participants earned certification, the lowest passing proportion of the five runs.
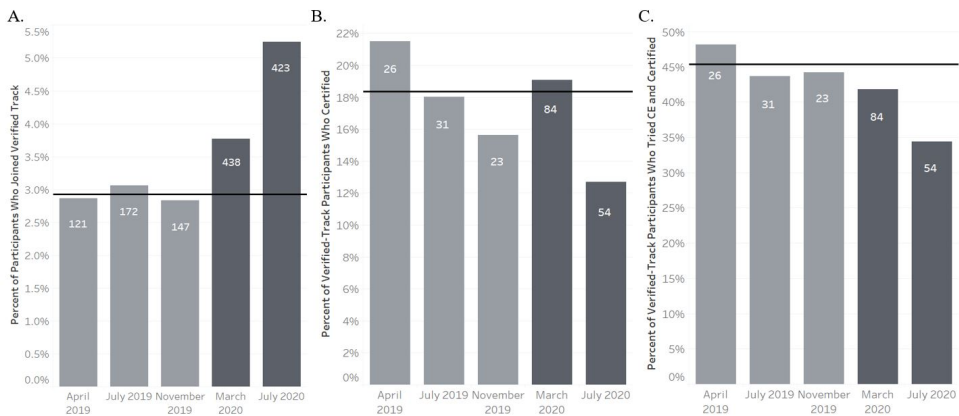

Figure 8: Percentages and counts of participant verification and certification. Percentage (y-axis) and count (number at the top of each bar) of (A) participants registered for the verified track, (B) verified-track participants who earned a certificate, and (C) verified-track participants who attempted the content exam, scored higher than zero, and certified. Pre-pandemic runs shown in light gray, pandemic runs in dark gray, and count of participants making up the calculated percentage labeled in white on each respective bar. Pre-pandemic mean percentage denoted by the horizontal black line.

The massive shift in traditional education to online format could have contributed to the increase in the number of verified learners. To explore this hypothesis, in both pandemic runs, the percentage of learners with an email domain associated with a higher education institution increased for verified-track and certified participants (Figure 9). In particular, the percentage of certified participants with a university-affiliated email address was two to three times that of pre-pandemic runs. The proportions of learners and participants with a university-affiliated email address remained similar, both to each other and between all five runs of the course.
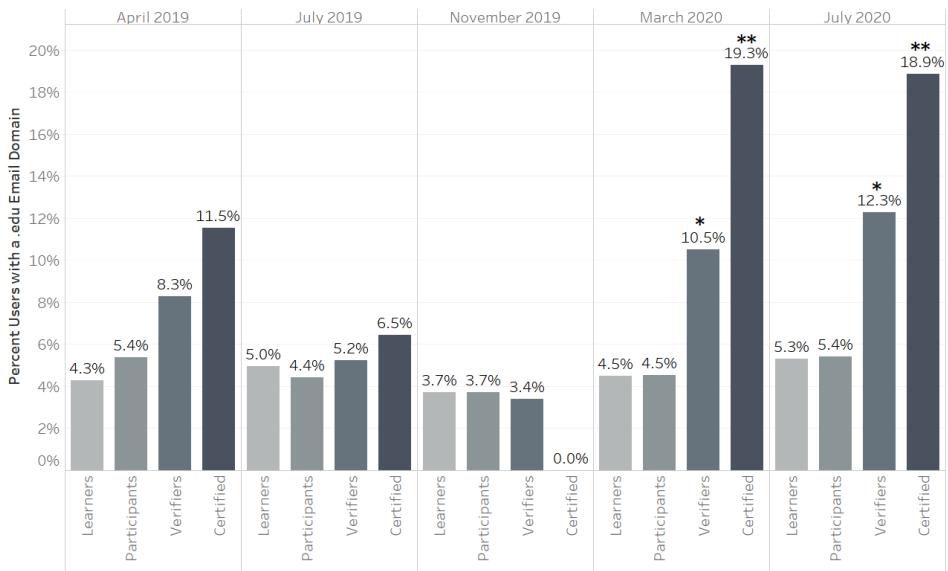

Figure 9: Percentage of learners registered with a higher education-associated email address. We calculated the percentage of learners registered for the course run with a ".edu" email address among all learners, participants, verified-track (verifiers) participants, and certified participants. Asterisks indicates a significant difference between pre-pandemic and pandemic percentages of verified-track participants (*, $p = 0.030$) and certified participants (**, $p = 0.030$).

The lower percentage of learners earning certification during the July 2020 run prompted us to investigate learner scores. As only verified-track participants could earn a passing score in the course if they took the competency exam, scores give
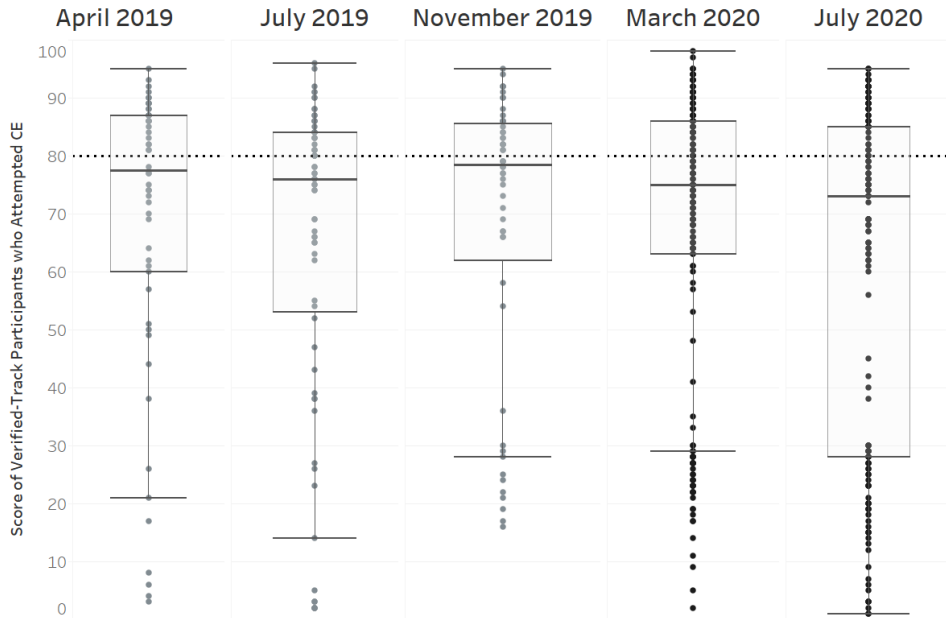
Figure 10: Verified-track participant scores. Boxplots showing scores of verified-track participants who attempted the competency exam and earned a score higher than zero. Horizontal dotted line denotes the passing score (score required to earn a certificate).

more insight into the range of performance of verified participants attempting the competency exam. We analyzed the scores of verified-track participants who attempted the competency exam (Figure 10). We found that verified-track participants earned similar scores during the March 2020 run as those in prior runs of the course. However, in the July 2020 run, more verified-track participants earned lower scores than in prior runs, which resulted in the lower certification percentage (Figure 8).

3 Conclusion

We hypothesized that the COVID-19 pandemic increased learner engagement in an introductory biology MOOC. As noted broadly [17, 16], we found an increased number of registered learners during the two pandemic runs relative to the three

pre-pandemic runs for this MOOC. A sharp increase in the rate of enrollment per day occurred shortly after the WHO declared the COVID-19 pandemic in March 2020 [18], but that rate and total enrollment level did not continue during the July 2020 run. This indicates that the unprecedented enrollment during the early months of the pandemic are not continuing throughout the pandemic or likely post-pandemic. MOOCs offered multiple times tend to experience a drop of about 25% in total enrollment per each repeat [3], but this course did not show this trend, even prior to the pandemic.

We next focused on the proportions of learner participation and engagement. We normalized proportions to the participant numbers, meaning that similar percentages corresponded to vastly different numbers of participants. For example, the 2,100 problem-engaged participants in the April 2019 run and the 5,600 problem-engaged participants in the March 2020 run are both around 50% of participants in that respective run. We chose to evaluate in terms of proportions to understand if engagement increased independent of enrollment numbers that fluctuate.

Since overall engagement metrics did not indicate the individual depth of engagement, we further investigated the individual measurements of participant engagement. Among video-engaged participants, the March 2020 certified participants viewed far more unique videos than the same subcategory of learners in pre-pandemic runs, while the July 2020 participants viewed far fewer. This latter result is especially surprising, as we expected verified-track and certified participants to view most of the videos given that previous studies showed these learners are more motivated to engage with course materials [13, 12]. Participants certified in the July 2020 run are perhaps repeat learners who have already explored the content in a prior run and are returning to the course after already taking it. Perhaps these certified participants are taking this MOOC concurrently with an outside biology course, thus necessitating less video viewing to earn a passing score as we did find more ".edu" learners certified than prior to the pandemic. However, we found increased play-per-video ratios in both pandemic runs indicating increased engagement for the participants watching videos. A higher play-per-video ratio could represent participants taking more detailed notes, processing information within the videos, or re-watching video content [9].

The 2020 course runs showed little change in patterns of unique problems attempted among problem-engaged participants, but normalized problem attempts per day revealed an overall higher engagement in the first pandemic run. Since the proportion of problem-engaged participants was similar to the other four runs, this result is likely due to increased engagement with problems at the individual level. Additionally, the high peaks of normalized problem attempts at the end of each run are likely due to verified-track participants "cramming" for the competency exam and taking the exam itself [2].

Unexpectedly, forum use had the greatest increase during the pandemic. We expected lower-effort activities, such as video watching, to have larger increases. This boost to forum participation could be in part to the sudden lack of in-person interactions due to COVID-19 stay-at-home procedures, but a further analysis of the forum would be necessary to determine the cause. In spite of the higher proportion of participants engaging with the forum, the individual number of forum posts did not differ widely between course runs. However, we found differences in the posting trends of learner subcategories, wherein certified participants tended to make more posts, except in the July 2020 run. Though outliers, more participants also posted more times in 2020 runs. It is important to note that the subset of learners who engaged with forums was the smallest of the types of engagement we analyzed in this paper. Forum posting requires engagement of higher effort than viewing a video or attempting a problem, and thus fewer participants posted to a forum. In the future, we can explore other aspects of forum engagement, such as low-effort reading/viewing the forum, responses, or even evaluate post content or length.

The increased percentage of verified participants during the pandemic runs could be attributed to the shift to online schooling, more partnerships with universities, or increased motivation to validate new skills gained for later employment. Specifically, in each pandemic run a higher percentage of verified-track and certified participants had university-affiliated email addresses, perhaps due to a teacher encouraging course registration. This is likely an underestimate of the proportion of learners who are associated with higher education, as university-enrolled MOOC learners may use a non-educational email address. Additionally, many services offered discounts on the paid verified track [5, 4]. The particularly high verification numbers in the July 2020 run could also be due to more returning learners from the March 2020 run, who might have used the prior run as a preview before committing to a paid certificate-earning track. We noted that, for this particular course, the certification percentage of all verified-track participants did not accurately reflect attainment, since many verified-track participants never attempted the competency exam. The much lower certification percentage in the July 2020 run resulted from more participants earning a lower score on the competency exam. This could be related to viewing fewer unique videos, struggling to understand video content, and even interacting less with the forum. This decrease in certification rate could also be due to learner "fatigue" or changing lifestyle as learners return to in-person activities.

We investigated a single introductory biology MOOC and found enrollment trends to be applicable to other MOOCs. However, engagement trends may not be generalizable for other courses, such as those outside biology, non-introductory courses, or for courses with more restricted learner demographics. Comparison of engagement metrics across courses could reveal the nature of course-specific

learner engagement and the impacts of subject matter on course engagement metrics. This deeper look into learner activity during the pandemic exemplifies the role of MOOCs in life-long learning, particularly in times of uncertainty, and reinforced their importance as an accessible learning option. While MOOCs had a massive surge in learners during the early months of the COVID-19 pandemic, prompting "The Second Year of the MOOC", [17] those numbers do not appear sustainable as enrollment numbers are trending back toward pre-pandemic values. Furthermore, learner fatigue, changing lifestyle, or loss of motivation has proved detrimental to performance, an unfortunate consequence of the pandemic for MOOCs.

4 Acknowledgement

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