# Apples vs. Oranges: Comparison of Student Performance in a MOOC vs. a Brick-and-Mortar Course

Michael Dubson*, Ed Johnsen*, David Lieberman†, Jack Olsen*,
and Noah Finkelstein*

*Department of Physics, University of Colorado at Boulder, UCB 390, Boulder CO 80309
† Department of Physics , CUNY/Queensborough Community College, Bayside NY 11364

**Abstract:** In the fall of 2013, we taught the calculus-based introductory physics course at the University of Colorado at Boulder and, at the same time we taught a MOOC version of the same course, through Coursera. Students in both courses received identical lectures, homework assignments, and timed exams. We present data on participation rates and exam performance for the two groups. We find that the MOOC is like a drug targeted at a very specific population. When it works, it works well, but it works for very few. This MOOC worked well for older, well-educated students, who already have a good understanding of Newtonian mechanics.

## INTRODUCTION

In the fall of 2013, one of us (MD) was the primary lecturer in the first-semester calculus-based physics course for STEM majors, Phys1110, at the University of Colorado at Boulder (CU). The initial enrollment in Phys1110 was 808 students. Almost simultaneously, we taught a massive open online course (MOOC) version, called "Physics 1 for Physical Science Majors", using the Coursera platform (www.coursera.org). Our MOOC had an initial enrollment of just under 10,000 students, rising steadily to 16,000 by the end of the 12-week course. The MOOC students were offered the same lectures, nearly the same assignments, and the same exams, as the brick-and-mortar students in Phys1110.

This paper describes the participation rates and student performance in this direct comparison between a MOOC and a brick-and-mortar course. We find that, for some students, the MOOC is as effective a learning environment as a brick-and-mortar course. When matched by the Force and Motion Conceptual Evaluation (FMCE)[1] pre-test scores, students who complete the MOOC do as well on exams as their brick-and-mortar counterparts. But while most brick-and-mortar students (> 80%) successfully complete the course regardless of background preparation, only a small fraction of the MOOC students complete the course, and those who do finish are predominately those with the strongest physics background, as measured by FMCE pretest scores and self-reported previous education in physics.

## BRICK-AND-MORTAR FORMAT

Phys1110 is a 1-semester course in which students attend three 50-minute lectures (MWF) and one 50-minute recitation section per week. The course uses several interactive engagement techniques. In a typical 50-minute lecture, the instructor is at the blackboard presenting a traditional lecture for about 15 to 20 minutes. The lecture is interspersed with 5 to 10 multiple-choice clicker questions (concept tests), class discussion, and demonstrations. Students are organized into clicker teams of 3 or 4 students, and are strongly encouraged to discuss and come to consensus with their peers before voting. Clicker scores have a soft effect (2% max) on the grade and are extra-credit. Reading assignments are from a free, online textbook written by MD[2].

In the weekly recitation sections, limited to 28 students, we use the University of Washington *Tutorials in Introductory Physics*[3] , a set of research-based group-work activities which emphasize sense-making and communication. Each recitation is led by a graduate student TA and an undergraduate Learning Assistant[4]. Weekly homeworks have two components: 1) 10 to 15 machine-graded online homework problems using the CAPA system[5] in which students are given 6 attempts for each problem and 2) TA-graded long-answer homeworks associated with the *Tutorials*. The online CAPA homework is a mix of conceptual questions and more traditional problems requiring multi-step algebra and calculus reasoning. The Tutorial homework is mostly conceptual and emphasizes sense-making. The exams, which were all

multiple-choice, emphasized conceptual understanding, with about half of the questions requiring little or no calculation.

CU students have access to the Physics Helproom, a 2000 sq. ft. open space, where they can work with peers or get personal assistance from TAs and faculty at any time during the working day.

We administered the FMCE diagnostic exam[1] in the first and last weeks of the course. The normalized gain[6] for this class was 0.59, which is considered high at CU.

## MOOC FORMAT

We endeavored to make the MOOC as similar as possible to the brick-and-mortar course, and emphasized this fact in all our communications with Coursera students. We marketed this MOOC as giving online students the experience of a real CU freshmen physics course.

The MOOC students were offered the same lectures with the same embedded clicker questions, got the same reading assignments, were assigned the same online (CAPA) homeworks with the same number (6) of allowed tries, with lectures and assignments delivered at the same pace, as were the brick-and-mortar students in Phys1110. They took the same exams with the same 90 minute time-limit. Students in both the MOOC and Phys1110 were allowed to use a pre-prepared formula sheet on the exams. MOOC students were allowed to begin each exam at any time during a 5-day window, but once they started the exam, they had 90 minutes to complete it.

To prepare the MOOC lectures, live Phys1110 lectures were recorded, and each 50-min lecture was edited down to about 30 min. Student-student discussion was edited out, since our room microphones could not pick up audience conversations. The clicker questions were embedded in the video as interactive break-points, and MOOC students had to commit to an answer before continuing with the video lecture.

Despite our efforts, the MOOC differed from Phys1110 in several important respects. To shorten the course somewhat, the MOOC consisted of the first 12 weeks of the 15-week Phys1110. The first 12 weeks comprised Newtonian Mechanics; the last 3 weeks covered fluids and some thermal physics, which were not included in the MOOC. The copyrighted Washington *Tutorials* could not be included in this free MOOC, so there was nothing in the MOOC resembling the weekly recitation meeting and *Tutorials*. There was no Tutorial homework; only the CAPA homework was assigned. And, of course, MOOC students had no direct access to staff and the Physics Helproom at CU.

Although MOOC students had no access to TAs, they did have access to their peers in discussion forums built in to the Coursera platform. We monitored the forums closely and found that they worked remarkably well. Students on the forums were universally respectful and eager to help their peers. The peer instruction was of very high quality and we never saw students passing around answers. We seldom needed to intervene in student discussions, because student questions were almost always answered well by other students.

Information on the MOOC students' demographics and attitudes were collected by surveys. The students' background knowledge of physics and learning gains were collected through FMCE pre- and post-tests. Students were encouraged to complete these surveys and diagnostic exams with 5% participation points toward a certificate of completion.

MOOC students who achieved a course score of at least 60% were awarded a certificate of completion. This level of achievement corresponded to a grade of C- for the Phys1110 students.

## MOOC DEMOGRAPHICS AND ATTRITION

Of the 10,000 students enrolled near the beginning of the MOOC course, about 2100 students (21%) took the demographics survey. Compared to our Phys1110 students, the MOOC survey-takers were older, more international, and better educated. Similar observations have been made in other MOOC studies[7,8,9]. The average age of the starting MOOC students was 31 years. Only 38% were from the U.S. 71% of them had some type of college or university degree; 25% had a Master's or PhD. 31% of the MOOC survey-takers were female, while in Phys1110, 18% of the students were female.

Although the MOOC students were older and better-educated than our CU freshmen, the distributions of FMCE pretest scores for the two populations were almost identical, as shown in Figure 1. Both MOOC and CU students show a bimodal distribution, with an elite top 10% who score high, but a large majority who score low, indicating a low background knowledge of Newtonian mechanics.

As is the case with most MOOCs, we observed a very large attrition rate[8]. Figure 2 shows the number of students in the MOOC who participated in lecture, homeworks (HW), and exams as the course progressed. 7200 students viewed the first lecture, 2300 completed HW 1, less than 300 completed the last few HWs and the final exam, and 225 students were awarded a Certificate of Completion. So, the MOOC completers comprised 2.2% of the initial enrollment of 10,000 students and 9.8% of those who completed HW 1. By contrast, 83% of the Phys1110 students initially enrolled passed the course with a grade of C- or better.
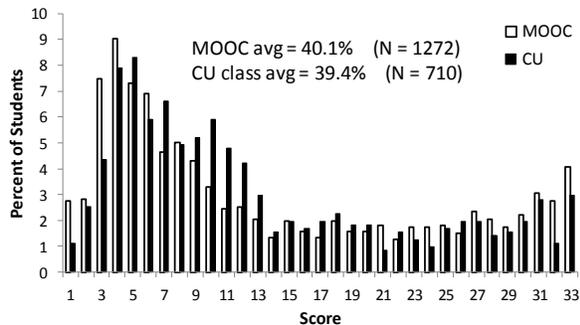
**FIGURE 1.** FMCE pretest scores (out of 33) for the MOOC students and the CU Phys1110 students.
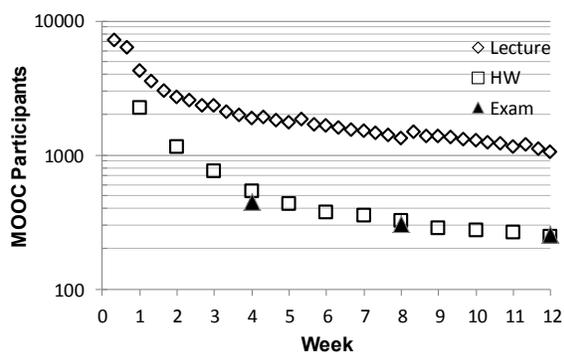


**FIGURE 2.** MOOC participation vs. time. Note that the vertical axis is logarithmic.

## EXAM PERFORMANCE

The MOOC students were given three tries for each timed exam, but were instructed to use extra tries only if needed due to internet connection difficulties. Most exam-takers used only one try, but a significant fraction, about 30%, used 2 or 3 tries, and these multiple-attempt students had an average score that was about 10% higher than the single-attempt students. In this section, we report only on data from the single-try exam takers, to get a fair comparison with the CU brick-and-mortar students.

The distribution of scores for exam 1 is shown in Figure 3. The MOOC students who took the exam did slightly better than the Phys1110 students. However, MOOC students who took the exams were strongly self-selected and, on average, had a significantly stronger physics background than the Phys1110 students.
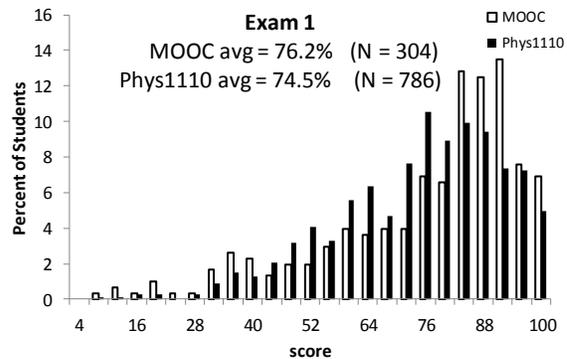


**FIGURE 3.** Exam 1 scores, MOOC and Phys1110.

Figure 4 shows the average FMCE pretest scores for the two populations vs. course milestone. While curve is nearly flat for the Phys1110 students, reflecting their small attrition rate, the MOOC students who take the exams form an increasingly better-prepared group as the course progresses. Less well prepared MOOC students drop out at a much higher rate than their Phys1110 counterparts.
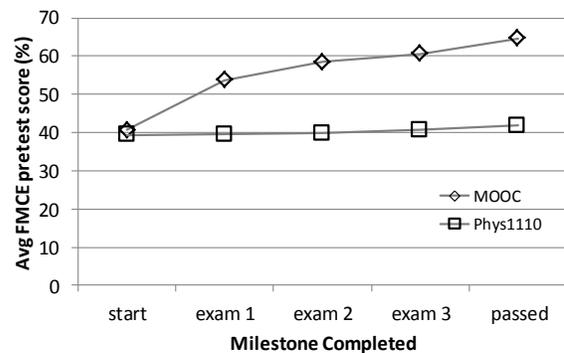


**FIGURE 4.** Average FMCE pretest score for population which completed the labeled milestone.
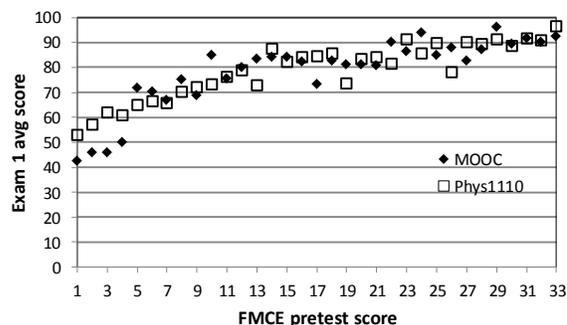


**FIGURE 5.** Average Exam 1 score vs FMCE pretest score.

Figure 5 shows the average exam 1 score for the two populations, sorted by FMCE pretest score. Note

the clear correlation between exam score and FMCE pretest score. Entering students with a better physics background do better on the exams, in both the MOOC and Phys1110. When matched by pretest score, the exam 1 performance of the MOOC and Phys1110 students are statistically identical, despite the fact that the MOOC students were, on average, considerably older and better educated. Similar results were found for exams 2 and 3, as detailed below.

Table 1 shows demographic data for the 2100 starting MOOC students who took the entrance survey and the 220 finishing MOOC students who successfully completed the course. The MOOC population starts out very different from our CU freshmen, and becomes even more different as the course progresses.

**TABLE 1.** Demographics of starting and finishing MOOC students.

|  | Starters | Finishers |
|---|---|---|
| Mean age | 31.4 yr | 39.5 yr |
| Percent female | 31% | 21% |
| Bachelor's or higher | 41% | 65% |
| Previous college physics | 50% | 60% |
| Mean FMCE pre-test | 40% | 65% |
| Mean FMCE post-test | N/A | 81% |

Table 2 compares exam averages for the two populations. MOOC students did somewhat better on the exams, on average. But, when matched by pretest score, as shown in Fig.5, and the bottom row of Table 2, the exam averages are nearly identical, statistically.

**TABLE 2.** Exam averages, MOOC vs. Phys1110, and differences between the averages.

|  | Exam 1 | Exam 2 | Exam 3 |
|---|---|---|---|
| MOOC avg | 76.2% | 74.7% | 69.1% |
| Phys1110 avg | 74.4% | 67.2% | 61.6% |
| MOOC−Phys1110 (raw score) | 1.8% | 7.5% | 7.5% |
| MOOC−Phys1110 (matched by pretest score) | 0.5% ±0.8% | 0.0% ±1.1% | 2.4% ±1.4% |

## CONCLUSIONS

Although the MOOC students and our Phys1110 freshmen are very different in age, educational level, and background, the two populations start with nearly identical distributions of physics background knowledge, as measured by the FMCE pretest. While most Phys1110 students (83%) passed the course with a grade of C- or better, only a small fraction of the MOOC students finished. In the MOOC, about 2% of enrollees, and about 10% of those who completed homework 1 went on to pass the course. The MOOC students with weaker backgrounds strongly self-selected out, while most of the Phys1110 students with weaker backgrounds managed to stay the course. The exam performance of the MOOC students who did complete the course was nearly identical to the performance of their brick-and-mortar counterparts, when matched by FMCE pretest score. This identical exam performance is surprising, given that the MOOC completers were considerably older and significantly better educated. This suggests that MOOCs are effective learning environments only for a small, select demographic – older, well-educated students, with a strong physics background and who possess a combination of self-discipline and motivation[10]. This population is a very different group than our college freshmen.

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