Active Learning about Structures through a Massive Open Online Course (MOOC)

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Is it possible to incorporate active learning strategies into a Massive Open Online Course (MOOC)? Will learners complete hands-on activities proposed through a MOOC? Are learners who are sent a set of supplies for the hands-on activities more likely to participate in the activities? Are these learners more engaged in the course? If learners are asked a set of preliminary questions will they be more engaged in the course? Data from a MOOC entitled The Engineering of Structures Around Us is used to answer these questions and to guide teaching of this and other courses.

Active Learning
A recent meta-analysis that included 225 studies found that student performance and retention in science, math, technology, and engineering courses increased when active learning strategies were used.\(^1\) Student performance on exams was found to be 6% higher when active learning was used and students in courses that included active learning were 1.5 times less likely to fail the course.\(^1\) Other studies support the finding that active learning results in improved engagement in engineering and across disciplines.\(^2,3,4\)

What is active learning? Active learning encompasses a broad range of activities that engage the students in meaningful learning.\(^2,5\) While homework and laboratory sessions likely include meaningful learning activities, advocates of active learning focus on approaches that take place in the classroom in place of traditional lectures.\(^2\) Felder and Brent use the following definition for active learning: “anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes” (p. 2).\(^6\) Active learning strategies include the use of clicker questions in class, peer instruction, inquiry-based learning, collaborative learning, and problem- and project-based learning.\(^4,5,6,7\)

Many active learning strategies have been used successfully in classrooms but how can these strategies be implemented in a MOOC?

MOOCs
What is a MOOC? MOOC stands for Massive Open Online Course, a term that was first coined in Canada in 2008.\(^8\) A MOOC is a course, meaning it meets a set of learning objectives and is more than just a couple of videos. MOOCs are free, though some charge a small amount for a certificate, and open to anyone in the world. As for the massive part, there are typically thousands, even hundreds of thousands of people, registered for each MOOC.\(^9\)

Most MOOCs include a series of instructional videos followed by questions. While the questions included in typical MOOCs likely promote thinking, do they qualify as active learning? Is truly active learning possible in a MOOC? Can active learning increase engagement and completion rates, which tend to be low?\(^10\)
The Engineering of Structures Around Us

The goal of the course, which targets high school students and beginning undergraduates, is to expose them to the engineering of structures, including the more creative sides of engineering. Can they develop structural vision? Or an ability to look at and critically evaluate structures? By the end of the course, learners are expected to be able to:

- Describe how forces flow through structural systems;
- Discuss how and why structures were designed and constructed the way they were;
- Conceptually design and build prototypes of structures;
- Identify and classify structures around the world and in their communities.

The Engineering of Structures Around Us is separated into six separate Concepts: Design, Tension, Compression, Tension and Compression, Shear and Bending, and Overall Response. Each of the six concepts is designed to take the learners less than 10 hours to complete. While the course is set up such that each week focuses on a different concept, students may work through the course at their own pace. The course was officially offered from May 5 through June 19 of 2015 but was left open and continues to be accessible, though discussion board monitoring and certification are not available in this archive-mode version of the course.

Each of the six Concepts includes approximately 45 minutes worth of videos. Video segments are short, less than 10 minutes in length, as research shows that the time spent watching videos drops off significantly after 9 to 12 minutes. Videos that incorporate more math are done using a lightboard that was built in-house and is shown in Figure 1. The lightboard allows the instructor to face the camera and learners while writing on the board.

As with most MOOCs a set of questions is posed after each video. These questions include multiple choice questions and matching questions but also open-ended essay questions. In an effort to better engage the learners (and promote active learning) a series of preliminary questions was also posed at the beginning of each Concept to hopefully get learners thinking about the material to be presented. Only half of the class received the preliminary questions so that the impact of these questions on student engagement could be investigated. This set of preliminary questions included an Owl's Dilemma problem each week. Owl is a fictitious character created in collaboration with illustrator, Katherine Roy (http://katherineroy.com/). The goal of including Owl was to try to make engineering less intimidating and to help put the material into context.

Figure 1. Lightboard

Figure 2. One of Owl's Dilemmas; illustration by Katherine Roy
Figure 2 depicts *Owl’s Dilemma* for week 3, which focuses on compression.

Each week learners are asked to participate in online discussions with their peers. In addition to an open-ended discussion question, they are asked to share an image of a structure in their community each week through the *Share Your World* discussion board.

In another effort to encourage active learning and engagement, each of the six weeks of the course includes at least one hands-on activity such as designing and building a model of a cable-stayed bridge, a tensegrity structure, and a cardboard chair. Instructions, both written and through video, are provided for each activity but learners are encouraged to be creative and to use whatever materials they have available. To encourage more learners to participate in the hands-on activities 500 learners received an activity kit that included all of the supplies needed for each of the activities. While other MOOCs provide lists of supplies needed for the course, few, if any, have sent out supplies to students.

Knowing that not all learners may be able or willing to build physical prototypes, six virtual simulation tools are included in the MOOC as well. Working with a computer programmer, David Souther, the following six simulation tools were developed, each of which focuses on a different concept: tension, compression, arches, trusses, beams, and building oscillations.

Learners are asked a set of guiding questions to help them experiment using the simulations. Figure 3 shows the simulation tool for beams. Learners see how the shear forces and bending moments change as they adjust the length of the beam, load type and amount, cross-section type and materials, and support position.
Overall Engagement and Performance
The *Engineering of Structures Around Us* was offered in the spring of 2015. Over 15,000 students have enrolled in the course, with over 12,000 enrolling before the official end date. Though the course is officially done, it remains open and accessible in archive-mode, meaning that the discussion boards are no longer being monitored and learners may not earn a certificate. About 100 learners continue to enroll every week. Learners of all ages have enrolled in the course, with the median age being 27 and ~42% of the students under the age of 25. About 20% of those enrolled are female. Geographically, learners have participated from 171 countries, with 21% of the learners from the US, 13% from the India, 4% from Egypt, 4% from Brazil, 4% from the United Kingdom, 3% from Spain and <3% from many more countries around the world.

As with other MOOCs, many of those who enrolled in the course never actually participated in any course activities. Figure 4 shows the number of people who watched at least one video or answered at least one question in Weeks 1-6, the official weeks that the course was offered. In week 1, ~3,900 people, or 38% of those enrolled at the time, watched at least one video or answered at least one question. As shown in Figure 4 and is typical for MOOCs, participation decreased as the course progressed, with only ~1500 people, or 14% of those enrolled at the time, engaged in the course at the end of Week 6. 5.2% of the learners who were enrolled in the course on the official end date received a certificate, meaning they passed the course. Again this is fairly typical of MOOCs, most of which issue certificates of completion to 2 to 10% of the learners. While higher completion rates are nice, everyone enrolls in MOOCs for different reasons and often learners focus on a single concept or idea, get out of the course what they need and thus don’t need to complete the entire course. Further, MOOCs with the highest completion rates tend to be those that require only the completion of multiple choice questions, which are graded automatically. Courses that use essay questions and peer grading tend to have the lowest retention rates.

The *Engineering of Structures Around Us* included multiple-choice questions that were automatically graded but learners were also required to post images, participate in discussions, share images, and design and build prototypes in order to receive a certificate. Given that the bar was set fairly high in the course, a completion rate of 5.2% seems fairly good; few courses have completion rates higher than 10% and many have completion rates around 2%.

The images that learners shared of structures from around the world were one of the most interesting aspects of the course. Learners posted images from their communities that represented a concept or structural element that was being discussed in the course that week. Three of the structures posted by learners during week 3, which focused on compression, are shown in Figure 5. Learners were asked to include arrows indicating loads (black arrows), the
flow of compression through the structure (red arrows) and support forces (white arrows). While learners did not always show the arrows perfectly, most seemed to grasp the basic idea of how forces flow through a structure. The Share Your World discussion board was fairly active: ~1800 learners (or ~18% of those enrolled at the time) posted to the discussion board during week 1, over 800 during week 2, dropping to 340 during week 6.

Figure 5. Share Your World Images Posted by Learners

A key aspect of the course was hands-on building. Learners were asked to design and build at least one prototype each week: a marshmallow tower and a cardboard chair in week 1, a cable-stayed bridge in week 2, an anti-funicular form in week 3, a tensegrity structure and truss in week 4, a beam or shelf in week 5, and a single-degree of freedom system and table in week 6. And people actually jumped in and built things and posted images of what they had built! They used all sorts of different materials and were creative with their designs. The goal of having them build structures was to allow them to feel how different structures behave and how different design decisions impact the behavior and buildability of the structure. Figure 6 show images of cardboard chair designs posted by learners during week 1. If learners did not have materials available or were too busy to build an actual chair out of cardboard they were encouraged to sketch some designs by hand or use SketchUp Make, a free online computer-aided design tool.

Figure 6. Cardboard Chair Designs Posted by Learners

Images of tensegrity structures built by learners are shown in Figure 7. Note the range of different materials used by the learners to construct the tensegrity structures. Tensegrity is a term that was coined by Buckminster Fuller, a combination of ‘tension’ and ‘integrity.’ Tensegrity structures use a combination of compression and tension to create stable, but flexible systems.
Figure 8. Preliminary Question: What do these images have in common?

Research Questions
Part of the reason for offering the MOOC was to help answer the following questions:
- If learners are asked a set of preliminary questions will they be more engaged in the course?
- Are students who were sent a set of supplies for hands-on activities more likely to participate in the activities? Are these learners more engaged in the course?

In order to answer the first question as to whether learners were more engaged if they were asked a set of preliminary questions, the learners were separated into two groups, an A group and a B group. The A group was the Inquiry-Based Group. This group was given a set of 5-10 preliminary questions before any videos or content was delivered. As an example, learners were asked what the images shown in Figure 8 all have in common during Concept 2, which focused on Tension. Prior to starting Concept 3, which focused on compression, one of the questions they were asked was: ‘What factors affect how much load a column is able to support?’ The goal of these questions was to get the learners thinking about the material to be presented. Group B was given a single preliminary question.

The Inquiry-Based Group (Group A) was also presented with Owl’s Dilemma and asked to discuss possible solutions to the problem, again to get them thinking and engaging with the material. Figure 9 depicts Owl’s Dilemma for Concept 2, focused on tension. Along with this image learners were presented with the following dilemma: ‘Owl has too many books and needs to get them organized and easily accessible. As a first step Owl plans to build a bridge over to a second tree (yes, Owl can fly but flying is tough while carrying heavy books).’ And asked to respond as follows: ‘What type of bridge should Owl design? This week we’ll focus on tension; what types of bridges could Owl design that rely on tension? What design do you propose?’

Figure 7. Tensegrity Structures Posted by Learners
Because all learners, in both A and B groups, would be contributing to the same discussion boards, Group B was also presented with Owl’s Dilemma and an image (typically just an image of Owl) but not asked to consider possible solutions or to respond in any way.

One of the goals again was to answer the following question: If learners are asked a set of preliminary questions will they be more engaged in the course? What is engagement? There are many measures to consider for engagement from minutes of video watched to number of questions answered to number of students participating. There were many videos to choose from and extracting the data on number of minutes viewed by each student is not trivial; thus, the percentage of students from each group, Group A or Group B, who engaged with different aspects of the course was used to measure engagement. Learners were randomly assigned to Group A or Group B by the platform. For this study 2790 learners were in Group A and 2659 in Group B.

The first aspect of the course that was considered when comparing Group A and Group B was the Check Your Understanding section at the end of each Concept. The Check Your Understanding section includes a set of culminating questions, sixty percent of which must be answered correctly by learners in order to receive a certificate of completion at the end of the course. The hypothesis was that learners in Group A would be more engaged in the course and thus would be more likely to complete the Check Your Understanding questions at the end of each Concept. This hypothesis ended up not being true. Learners in Groups A and B were equally likely to complete the questions at the end of each Concept. Some weeks Group A had a higher completion rate, some weeks Group B had a higher completion rate and for all weeks the rates were quite close.

Further investigation did reveal a couple of trends, however. The two most significant trends were in the What do you Think (preliminary questions) and Owl’s Solution sections of the course. As discussed earlier both groups, A and B, were presented with a set of preliminary questions in a section called What do you Think, with Group A’s set focused on inquiry and 5-10 question long and Group B’s a single, fairly straightforward question. The percentage of students answering at least one question in this What do you Think section is given in Table 1. Interestingly, a higher percentage of students in Group B than in Group A responded to the What do you Think question during weeks 1 and 2. This trend reversed, however, in week 3 and by
week 6, 16.4% more of the students in Group A responded to the *What do you Think* questions. The hypothesis was that the preliminary questions presented to Group A learners would result in them being more engaged with the material. While it isn’t shown in Table 1, Group A students generally responded to all of the 5-10 questions that they were asked, a decent time commitment; Group B learners were asked to answer only one question. Thus, despite the time commitment, learners in Group A were more likely to respond to the *What do you Think* questions as the course progressed, indicating that they found them engaging and worth the effort.

Table 1. Percent of Learners in each group who responded to a preliminary set of questions

<table>
<thead>
<tr>
<th>Concept/Week</th>
<th>Group A</th>
<th>Group B</th>
<th>% Difference between Group A and B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept 1</td>
<td>39.82</td>
<td>48.18</td>
<td>-17.33</td>
</tr>
<tr>
<td>Concept 2</td>
<td>20.36</td>
<td>21.74</td>
<td>-6.34</td>
</tr>
<tr>
<td>Concept 3</td>
<td>12.98</td>
<td>12.45</td>
<td>4.23</td>
</tr>
<tr>
<td>Concept 4</td>
<td>10.72</td>
<td>9.97</td>
<td>7.53</td>
</tr>
<tr>
<td>Concept 5</td>
<td>9.21</td>
<td>8.39</td>
<td>9.84</td>
</tr>
<tr>
<td>Concept 6</td>
<td>7.92</td>
<td>6.81</td>
<td>16.37</td>
</tr>
</tbody>
</table>

*Owl’s Solution* was the other aspect of the course where Groups A and B seemed to respond differently. As a reminder, both groups were presented with an *Owl’s Dilemma* at the beginning of each week or Concept. The dilemma was presented in an inquiry-based fashion for Group A and required that they share their thoughts about the dilemma. Group B, on the other hand was just presented with the dilemma and not asked to comment on it. Both groups were asked to reflect on *Owl’s Solution* at the end of each week or Concept. Figure 10 shows the percentage of learners in each group who reflected on Owl’s Solution. Group A learners were consistently more likely to reflect on *Owl’s Solution* than Group B learners. In weeks 5 and 6, 12.9% and 15.4% more learners from Group A reflected on Owl’s Solution than learners from Group B. This indicates that Group A learners were more engaged with *Owl’s Dilemma* and *Solution* than Group B learners.

Figure 10. Percentage of Learners Reflecting on Owl’s Solution by Concept or Week
In addition to asking a set of preliminary, inquiry-based questions, 500 learners were sent an activity kit. These activity kits included all of the supplies needed to complete the hands-on activities presented in the course. Activity kits were sent out in an effort to encourage learners to engage in the course and complete the activities. Learners were required to request a kit; 587 learners requested a kit but only 500 kits were sent out for financial reasons. Learners who did not receive an activity kits were still encouraged to complete the activities using easy to find supplies such as tape, cardboard, spaghetti, sticks, and paper. The hypothesis was that learners who received an activity kit would be more likely to complete the hands-on activities in the course.

Figure 11 depicts the percent of students reporting that they completed hands-on activities by group for each Concept or week. As is shown, those learners who received an activity kit were consistently more likely to report having completed the hands-on activities relative to those who requested a kit and did not receive one and those who did not request a kit. Admittedly, those who requested a kit were likely more engaged in the course from the outset but it is still encouraging that the activity kits seemed to be a supportive element of the course.

![Figure 11. Self-reported participation in Hands-on Activities by group type](image)

### Conclusions

The goal was to answer the following questions: Is it possible to incorporate active learning strategies into a Massive Open Online Course (MOOC)? Will learners complete hands-on activities proposed through a MOOC? Were learners who were sent a set of supplies for hands-on activities more likely to participate in the activities? Were these learners more engaged in the course? If learners are asked a set of preliminary questions will they be more engaged in the course?

Are active learning strategies possible in a MOOC? And will student complete hands-on activities? Active learning strategies used in the course included a set of preliminary, inquiry-based questions and a series of both physical activities and virtual simulations. So yes, it is
possible to incorporate these strategies in a MOOC. While not all students completed the hands-on activities, many students designed and built prototypes and posted images online. The availability of activity kits, while requiring a decent effort, did seem to encourage learners to complete hands-on activities. As to whether learners who were asked a set of preliminary questions were more engaged in the course, the answer is less definite but they did seem more engaged with *Owl’s Dilemma* and *Solution* and were more likely to continue to respond to the *What do you Think* questions.

While this study has begun to explore questions related to active learning in MOOCs, many questions remain, such as: Are hands-on activities more important or are virtual simulations sufficient? What is the appropriate level of difficulty for questions? In what order do students tend to proceed through the course? Does the registration requirement present a barrier to completion? The MOOC will be re-offered in the summer or fall of 2016, focusing more effort on the development of A/B groups to answer additional research questions.

**Bibliography**