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Development and Implementation of a MOOC Introduction to Engineering Course

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Development and Implementation of a MOOC Introduction to Engineering Course

Abstract

In this evidence-based practice paper, the development and implementation of a new Introduction to Engineering course developed for the massive open online course (MOOC) environment will be discussed. In recent years, a number of universities and colleges have developed MOOCs. While this space within the educational landscape has garnered interest from many of the top schools worldwide, very few of them have actually provided pathways for students in these MOOCs to earn college credit. Most of the schools that have provided such pathways have focused on Master's level programs, rather than undergraduate programs. One first-of-its-kind initiative is Arizona State University's Global Freshman Academy (GFA) in which versions of all first year classes are being developed for this MOOC environment with options to receive college credit from Arizona State University (ASU).

The Introduction to Engineering course described in this paper was developed for a Fall 2017 launch as a part of the ASU GFA initiative. This course is the first Introduction to Engineering course offered with pathways for college credit in this MOOC environment. In an attempt to provide the same quality of education to online students as traditional students, this course integrates best practices such as active project-based learning, multi-disciplinary concepts, contextualizing course concepts within industry practices, ePortfolio documentation of skills, and collaborative peer engagement unlike anything currently available in Introduction to Engineering courses in the MOOC community. In the first offering of this course, 4,014 students were enrolled including 69 students who paid a small fee to be ID-verified in order to potentially receive a certificate for completion of the course; 22 students successfully completed the course. This paper describes the course goals, structure, and design including specific challenges related to designing a course for the MOOC environment. The implementation of the course will also be discussed, including preliminary data on the effectiveness obtained from an end-of-course survey administered to students enrolled in the first offering of the course. Insights gained from the first offering of this course as well as recommendations for future work will also be discussed.

Introduction

Massive open online courses (MOOCs) have attracted the attention of many colleges and universities in recent years. Since the term was coined in 2008, MOOCs have been a topic of significant debate in regards to their teaching effectiveness and intellectual property issues [1]. Despite the controversies surrounding MOOCs, companies such as Udacity, Coursera, and edX have offered many of these courses in which millions of students have enrolled. These companies have partnered with dozens of different colleges and universities to offer MOOC courses including Harvard, Stanford, and MIT from which these companies originated.

The potential and appeal for these MOOCs stem largely from their accessibility and reach. While MOOCs vary widely in their implementation [1-4], they are often characterized by their large class sizes (often with thousands of students enrolled in a single class), free or low-cost fee structure, and often with little to no enrollment requirements (such as prerequisites). This means that the course material is open to any student around the world that has a computer and internet connection. While the potential to engage many learners is huge, MOOCs often suffer from low completion rates [5-6] and often leave students feeling overwhelmed by discussion boards filled with posts and yet little interaction between students or instructors (if there even are instructors) [1,6].

Most MOOCs have some kind of internal credentials on their platform to recognize student's efforts in their courses such as completion certificates for individual courses or sequences of courses. For example, Coursera offers Coursera Specializations, which are particular series' of courses designed to focus on understanding specific topics [7]. Recently, universities have begun partnering with these MOOC providers to provide these online learners with opportunities to earn college credit or even degrees with varying levels of success. MicroMasters programs from MIT in the edX platform were first announced in 2016 [8]. Since then, more than 23 other universities from all over the world have developed their own MicroMasters programs including Georgia Tech's Online Master of Science in Analytics [9] and Delft's program in Solar Energy Engineering [10]. While a few schools have provided Master's level courses, very few have even attempted to provide pathways to college credit for undergraduate courses since the failed Udacity/San Jose State University partnership in 2013 [11]. Many other attempts at providing university credit for students who successfully complete their "MOOC" often incorporate some kind of fee structure that no longer make the enrollment open and hence have more in common with traditional online distance learning than actual MOOCs.

One first-of-its-kind initiative is Arizona State University's Global Freshman Academy in which versions of all first year classes are being developed for this MOOC environment with options to receive college credit from Arizona State University (ASU). Through this program, learners can take a course completely for free in the "audit track" which allows them access to all course material, but does not provide instructor grading of assignments or any kind of "verified" certificate of completion. For these students, the course is treated much like a traditional MOOC, but with the benefit of an instructional team that includes professors who monitor and participate in discussion boards and host live "Q&A" video sessions throughout the course. The innovative aspect of this course is that there is a parallel track that students can opt into which involves students paying a small course fee and registration/identification. These students will have their assignments graded by instructional staff and have the possibility of earning a “verified” certificate of completion including a course grade. After successfully earning a verified certificate, the student can pay an additional fee to convert that verified certificate into official course credit from ASU.

The Introduction to Engineering course described in this paper was developed and launched in the Fall 2017 semester as a part of the Global Freshman Academy (GFA). It is the first Introduction to Engineering course offered with pathways for college credit in this MOOC environment. This course has been designed to incorporate best practices such as active project-based learning, multi-disciplinary concepts, contextualizing course concepts within industry practices, documentation of skills in an e-portfolio, and collaborative peer engagement unlike anything currently available in Introduction to Engineering courses in the MOOC community. The course goals, structure, and implementation of this course, including the best practices mentioned above, will be described in the next few sections. Preliminary course effectiveness results from the first offering of this course, including student performance and feedback from and end-of-course survey, will also be discussed along with instructors’ reflections on the experience.

Course Description

As described previously, this initiative and structure being developed by ASU as a part of the GFA preserves the openness and accessibility of a MOOC, while at the same time offering a pathway to university credit. Since this course must be equivalent in rigor and experience to the other Introduction to Engineering courses offered at ASU and yet still be able to accommodate thousands of students at a given time, it provided an interesting instructional design challenge. This course was developed for the edX platform as part of a partnership between edX and ASU.

During the end of the Spring 2017 semester and throughout the Summer 2017 session, a team of instructional designers and faculty members developed this course. The university already offered an online Introduction to Engineering course that was offered as part of the online engineering degree programs offered at Arizona State University [12], but that course assumes a structure that necessitates a capped class size and the verified identity of the students and hence was not appropriate for the MOOC environment. That existing online course did, however, provide insight into how to develop online projects and strategies to help instructors maximize their impact without over-burdening them. These design features will be discussed in more detail in the following sections.

This class was designed as a 15-week course that focuses on teaching concepts related to engineering design. Each week is broken up into smaller units, with each unit focusing on a specific topic. The topics for each unit can be seen in Table 4 in the Appendix. This class intentionally does not introduce the different engineering disciplines explicitly, but rather focuses on teaching skills that engineers use and encourages students to both document and reflect on those skills. The engineering disciplines do, however, appear in the course through a series of videos which are called “Day in the Life” videos. In these videos students hear from industry professionals and upper division engineering students about how the weekly topic is currently being applied within their projects and/or careers. Each unit consists of videos, readings, tutorials, discussion boards, and/or simulations which teach the students new concepts, and guide their practice in applying the skills being taught. Each week also includes deliverables such as ePortfolio reflections where students document and reflect on the new skills they are gaining, content mastery quizzes which test basic comprehension of the topics, and project documents that demonstrate students’ ability to apply the topic to their design projects.

The topics from each unit are applied to two different design projects: a 5-week open-ended project (Developing Value and Innovating Limitless Solutions also known as DeVILS) and a 10-week disaster relief project in which students learn and apply technical skills to design an aircraft for use in various natural disaster scenarios. In the DeVILS project, students are asked to identify a problem that they are interested in solving. Students then use the techniques described in the units to come up with a conceptual design which solves their identified problem. Various discussion boards are used to encourage students to interact with one another and even use other students in the class to better identify and define a problem to solve. This leverages the wide range of student experiences and backgrounds that MOOC enrollment offers to help students understand the problem from different perspectives. It basically treats other students as potential users of the finished product and allows for a more thorough problem definition experience based on “user” feedback. For this project, students submit a written deliverable detailing their chosen problem near the beginning of the course. This timing allows them to receive instructor feedback early on. The final deliverable for this project includes creating a proposal presentation in the form of notated slides to present their conceptual design, which includes a formal list of requirements, summaries of alternative solutions, a CAD model, as well as an explanation of the decision process they used which led to the proposed design.

The 10-week disaster relief project is meant to provide students with an opportunity to learn and apply specific technical skills to a large systems-based project, while ensuring that students continue to recognize the human need detailed by various customer statements. The project is broken up into subsystems and each subsystem is addressed one at a time to walk students through the development of a complete aircraft design. These subsystems include aircraft wing design, structural wing support design, aircraft interior layout and payload design, external visual representation of the aircraft, and automated component design. Students are provided with simulators that were developed in-house to experiment with different design options for their aircraft, and once a subsystem is developed students must go back and see how the design changes in one subsystem affect other design choices that had been made prior and iterate on their design. There are also different design opportunities students can choose from based in different regions of the world which experience a variety of natural disasters at different frequencies. Wildfires, hurricanes, tornadoes, earthquakes, and a zombie apocalypse are all possible scenarios offered to the students for consideration when designing. Each disaster type might also require different performance specifications and thus trade-offs must be made between the benefits of servicing a particular kind of disaster in a particular region and the costs of building an airplane that meets those specifications. This project incorporates all of the engineering skills taught in the class and culminates in a final technical report.

The class is managed by two instructors who also teach on-site versions of the course at ASU, and TAs who are hired for grading and managing the discussion board. The primary responsibility of the instructors is to serve as content experts who engage with students in the discussion boards and help direct students as they are learning to apply the concepts. The teaching team interacts with both audit track and verified track students in the discussion boards but only the verified track students will ever have assignments graded by a member of the instructional team. The instructors also hold YouTube live video sessions periodically throughout the semester and answer questions from the students during these sessions. These sessions allow for instructors to provide real-time clarification to students who can submit questions through the interactive media capabilities. The purpose is to help students build some kind of connection with the faculty members and help them to know they are not alone in the course. Making these kinds of faculty-student connections has been shown to be important for student success and retention [13] in on-site classes and thus was an important part of the course design for the MOOC environment. The course is designed to be taught by one or two faculty members as a part of their teaching load supplemented with enough TAs (at 20 hours per week) to manage the workload of the enrolled students. Since grading is only based on the number of verified students, this enrollment number is used to justify and determine the number of TAs that are hired (typically one TA for every 80 verified students).

Throughout the course, there are optional ungraded assignments, such as activities and discussion boards, as well as graded assignments. Types of graded assignments and the grade breakdown can be seen in Table 1. For the ePortfolio and project related assignments, detailed rubrics have been developed and are provided to students. Three forms of assessment are used that allow the students to receive feedback on their work: peer-assessment, self-assessment, and instructor-assessment. Depending on the type of feedback desired, different combinations of these three assessment types were used for a particular assignment. Students who are on the Audit track self-assess these assignments following the rubrics, using the self-assessment tool that is available on the edX.org platform. All of the ePortfolio assignments are graded by the instructional team for the ID-verified students and they receive feedback from content experts throughout the course. Both assignments for the DeVILS Project, as well as the final report for the 10-week project are also instructor-graded for these students. The seven project memo assignments for the 10-week project are self-assessed for both ID-verified and non-ID-verified students, in order to make the workload more manageable for the instructional team. For some assignments, drafts are submitted for peer assessment before final drafts are submitted to provide students the opportunity to receive preliminary feedback from their peers on their work. The Disaster Relief Project Memos were also designed in such a way that the content could be used for a significant portion of the different sections of the Final Report.

The final exam is a necessary and important assignment for the ID-verified students. This exam utilizes an online proctoring service that records the students as they take the exam. They must pass this proctored exam in order to pass the class and receive a verified certificate for the course. This helps to ensure that the person who is doing the work is receiving the credit since this is a gateway which links their coursework to a specific person who has verified their identity in the course platform. If students are caught cheating, they will fail the final exam and not get credit for the course.

Table 1. Grade Breakdown for the Graded Assignments

Item (number of assignments)	Weight (%)	Proctored	Graded
ePortfolio (10)	25	No	Self: Audit Track Instructor: ID-verified
Content Mastery Quizzes (14)	5	No	Autograded
DeVILS Project - Problem Definition (1)	3	No	Self: Audit Track Instructor: ID-verified
DeVILS Project - Presentation (1)	12	No	Self: Audit Track Instructor: ID-verified
Disaster Relief Project Memos (7)	15	No	Self
Disaster Relief Project Final Report	30	No	Self: Audit Track Instructor: ID-verified
Comprehensive Final Exam	10	Yes: Audit Track No: ID-verified	Autograded

Course Implementation

This 15-week course was first offered during Fall 2017. During the first offering, there was a total enrollment of 4,014 students with 69 ID-verified students at the end of the semester. The final number of ID-verified students is slightly lower than the peak number of 91 ID-verified students observed earlier in the semester due to various natural disasters necessitating some ID-verified students to drop the course and request refunds from edX. The median self-reported age is 27 and the majority of the learners were under the age of 40 (see Figure 1 for age distribution). The self-reported level of education was also varied; 36.6% of the students have a high school diploma or less, 41.5% of the students have a college degree, and 18.8% of the students have an advanced degree. A breakdown of the student population based on highest degree achieved (self-reported) can be seen in Figure 2. The class was made up of 24.8% females and included students from more than 147 different countries or regions. The largest countries represented were the United States (22.9%), India (9.9%), and Canada (3.9%). The number of active learners peaked at the beginning of the course in August and the number dropped from 1,353 to around 80 at the end of the course. This large drop is partially because many people participated in the Week 1 introduction activities, but did very little in the rest of the course. Some of this may just have been that many of those enrolled were just interested in checking out the new course with no intention of completing it from the very beginning. It is encouraging to note, however, that out of the 69 ID-verified students, 22 received their certificate and at least 3 of those have already received ASU credit (the rest of the ID-verified students who successfully completed the course have one year to convert their certificate to college credit). Most of these 22 students submitted all graded assignments, and for those who did not, they have only missed at most 4 graded assignments. Eighteen of the 22 students received a grade of 90% or higher. Most of those who were ID-verified but did not receive credit did not attempt the final exam. While a 32% completion rate of ID-verified students is still much less than in on-site classes, this number is significantly higher than many MOOC completion rates [5-6]. There is still work to be done in this area and potential changes to the course aimed at improving the completion rate will be discussed later in this paper.

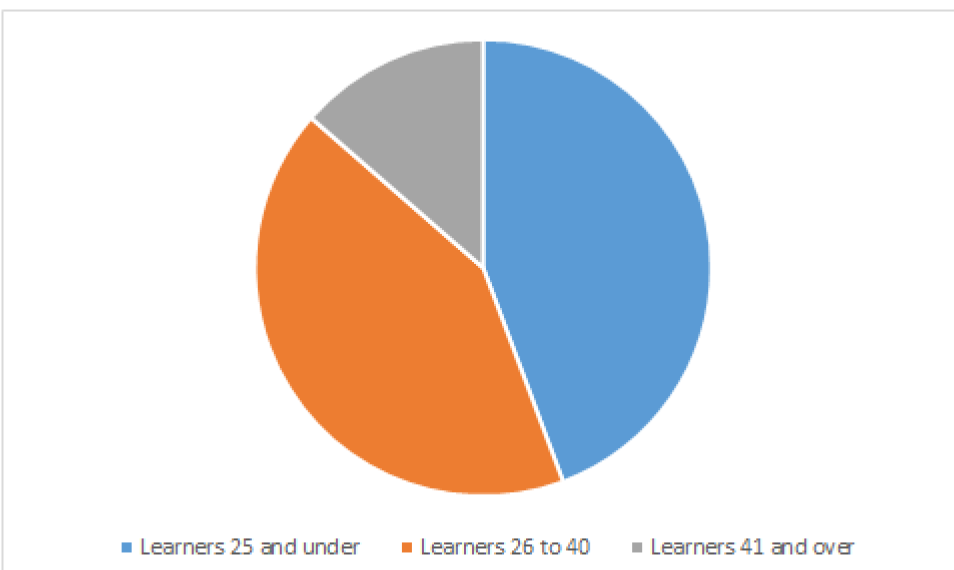

Figure 1. Age distribution of students enrolled (self-reported)

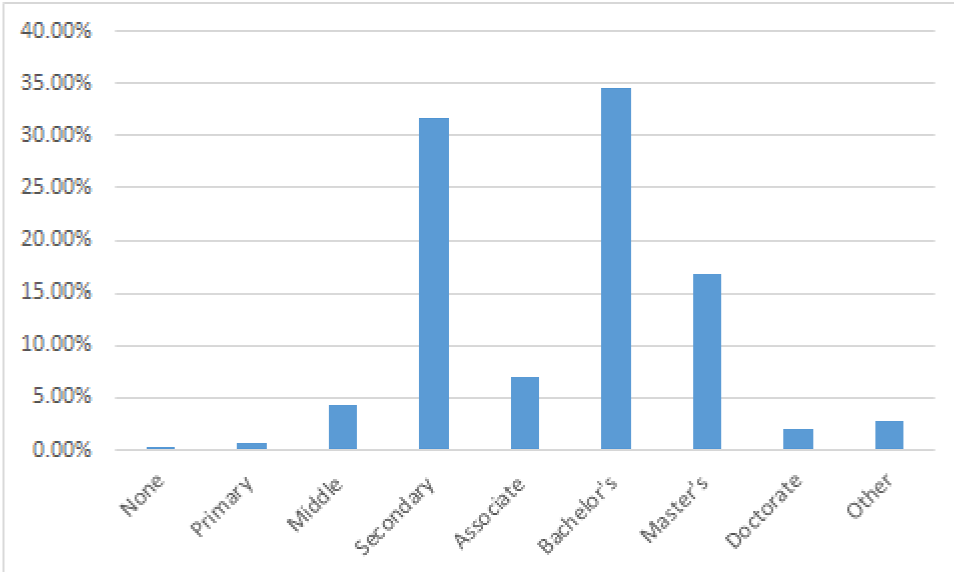

Figure 2. Education background of learners (self-reported)

An end-of-course survey was administered at the end of the course to gain learners' feedback. The survey contained both rating scale questions and open-ended questions. Due to the very low survey response rate, it is unclear how representative these students are of the class as a whole and conclusions are difficult to make.

Overall, responses from the majority of the survey participants indicate that they had positive opinions about the course. A majority of students (68%) agreed that they would likely recommend this course to someone else (see Figure 3). In addition, the participants found the content interesting and thought that what they learned in this course would help them after they graduate and/or go to work: all of them responded with strongly disagree (10 out of 13 participants) or disagree (3 out of 13) with statements that stated the opposite .

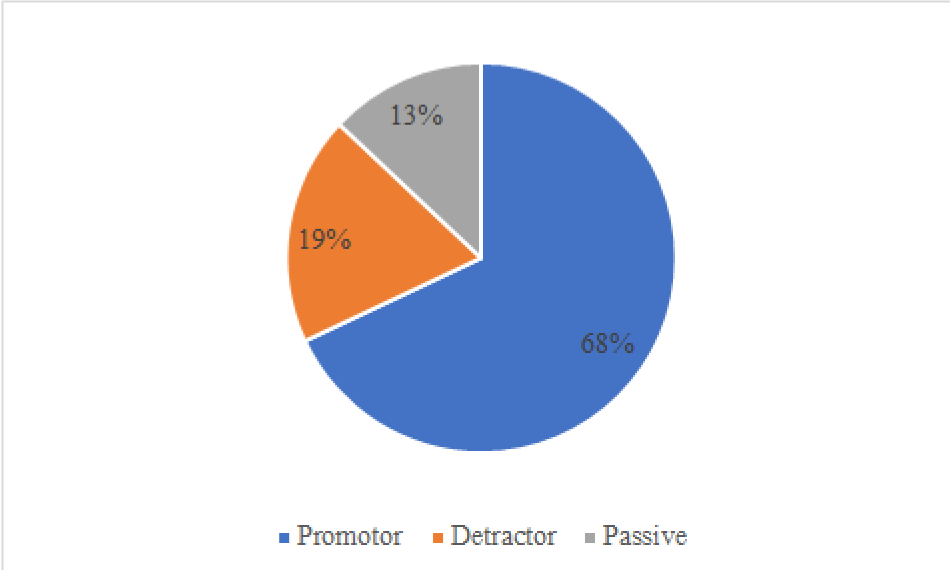

Figure 3. Survey results for question ‘how likely are you to recommend this course?’

Table 2 shows the average scores given by students for the usefulness of the different content items featured in the course. Each item in the survey had different numbers of responses and so the number of responses are also included in Table 2. Out of the various learning elements, ‘projects’, ‘instructor video lectures’, and ‘content mastery quizzes’ stood out as the top three that were most useful in helping them achieve their goals. This result matches that from their answers to one of the open-ended questions, “what in your course experience did you find helpful in meeting your course goals?” In the 9 responses to this open-ended question, 3 mentioned videos, 2 mentioned projects and others mentioned various things ranging from having to-do-lists in the course, to the course schedule. One of them mentioned that “having a lot of tangible products at the end, from all the different CAD renderings and models and Portfolio” has been the most useful. Note that “Outdoor Activities” is a standard item for the edX survey but does not really apply to this class although students may have taken this to mean the customer identification aspect of the DeVILS project or some of the early design challenges where they build things like paper towers. The fact that discussion board activities are rated so low may indicate that these could be improved in future offerings of the course.

Based on the results of the open responses (note: not all respondents completed all survey questions), of the 11 responses, 20.7% indicated that they could apply the concepts in their present or future job based on their performance and 16.7% of 9 students that provided feedback indicated that they were eligible to or have already purchased Arizona State University credit. 81.3% of 16 participants felt that there was a proper amount of times within the course when they were asked to provide feedback. 56.3% of them felt that the course was more difficult than expected, and the other 43.8% felt the level of difficulty met their expectations.

Table 2. Usefulness of the different learning elements

Learning elements	Average (out of 5)	Number of responses
Projects	4.69	16
Instructor video lectures	4.63	16
Content mastery (Cerego)	4.38	13
Case Studies	4.38	13
Reading materials	4.36	14
Interactive exercises	4.27	15
Outdoor activities	4	5
Journaling / reflection activities	3.92	12
Videos from guest speakers	3.8	15
Discussion boards activities	3.21	14

Participants were also asked to rate the effectiveness of the instructors and course team, as well as their confidence in their performance in the course, on a Likert scale of 1-5, with 1 being strongly disagree and 5 being strongly agree. The results for the 13 total responses to these questions are shown in the Figure 4.

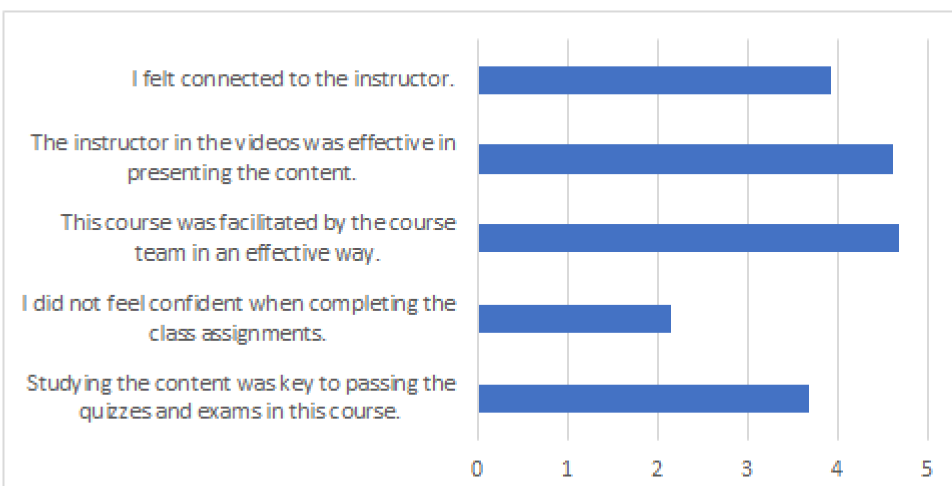

Figure 4. Mean scores for the five survey questions (n=13)

Sixteen participants provided written responses for positive feedback and the results are summarized in Table 3. The projects and instructors were mentioned most frequently in the positive feedback. The participants felt that the projects were fun and they liked that they had the freedom to either choose which problem they want to focus on or to come up with their own idea. They have also appreciated that the instructors were very helpful both in the live Q&A sessions and by providing timely responses in discussion boards.

Table 3. Coded responses to the open-ended positive feedback question

Item	Frequency
Projects (fun; open-ended)	5
Instructors (responsive; helpful; engaging)	5
A Day in the Life Videos	3
Topic (interesting; variety)	2
CAD/Fusion 360	2

Ten participants also provided suggestions to improve this course. One of the main suggestions was to have more frequent instructor feedback for the Disaster Relief project memo assignments, which were all peer and self-assessed for both ID-verified and non-ID-verified students. Another suggestion was to have a more manageable workload for some of the weeks. Some changes have already been made for the spring offering and others will be made in future offerings to address these issues; these changes will be discussed in the next section.

From an instructor's perspective, despite the large numbers of students, the discussion boards were still manageable even at the peak participation rate. It was easy to determine who the active members in the course were as they both posted responses and often replied to other student's posts. The scalability aspects seem to be manageable through the use of increased numbers of TAs for grading based on the suggestion given earlier in the paper. The largest part of the workload comes from monitoring the discussion boards. The TAs and Instructional Designers were helpful in identifying posts that needed an Instructor to address. The biggest issue was the lack of continued dialogue on posts. Most of the responses that the instructors gave were the end of the discussion and students would often not engage in back-and-forth dialogue in the discussion boards. This low level of student engagement through dialogue was also observed with regards to the instructors' live "Q&A" sessions. The live sessions were good to show the instructors' personalities and help students understand what was coming up and how the things that they were currently learning would be applied in the future assignments. However, these live sessions were often poorly "attended" and so there were often not a lot of live questions being asked and few students seemed to have questions about the course content to ask in advance. Some of this may be the timing of these sessions, since there are students from around the world and many of them also have jobs that influence when they can be online. The live sessions were recorded and posted for all students to watch on their own time. The discussion boards seemed to be a better place to actually interact with students.

Future Work

After successfully completing the first offering of this course, the two themes of engagement and retention emerged as important things to begin to address. Based on the nature of the course and the MOOC environment, it is not expected that these two topics will be fully solved, but there were some things that were changed for the Spring 2018 offering of the course. There are also improvements planned for future offerings as well as marketing directions which may also impact the course development.

Since one of the concerns was engagement, especially during the 10-week project, optional discussion boards were added so that students could post what they were working on so that other students and instructors could give feedback and encouragement. This is meant to help the students feel less isolated as they are working through each subsystem of the project but also to help students benchmark their design against others in the class. It has also been a point of emphasis for the teaching team to include questions to students when responding to posts to elicit further insights from that student or to invite other students to join in on the conversation. In the future, it would be interesting to see if this increases the length of these threads. There was also a big push to get students to ID verify since having more students that were ID-verified seemed to produce more active participation among the students. For the spring offering, the number of ID-verified students is comparable to the Fall 2017 offering despite the number of audit track students decreasing by about 50%. It will be interesting to see if the larger percentage of ID-verified students affects the participation and/or completion rates and how the course is perceived by students.

Changes are also being planned for the Fall 2018 offering. These include making more of the assignments for the 10-week project instructor graded so that the ID-verified students get more feedback from trained assessors. This is to address one of the concerns mentioned in the student feedback from this first course offering. Also, a new instructional module is being developed to address the role of peer feedback in the engineering profession as well as provide insights on how to give good feedback to other students, both in discussion boards and peer-assessment activities. Graded assignments related to giving feedback are also going to be included in the course. The hope is that this will inspire more students to engage with other students and pay more attention to the ways that they can help their peers through giving good feedback. The secondary byproduct of this is the hope that this will develop a stronger sense of community between students in the course.

Finally, the larger future vision for the course would be geared towards high school students who do not have access to dual enrollment engineering courses at their high school. Local partnerships are being worked out to use this course as a platform for high schools to help students earn credit before sending them off to a university to pursue an engineering degree. While the details of these kind of programs or collaborations have yet to be worked out, this would hopefully increase the number of ID-verified students in the course and, with appropriate support, help increase the retention rate. Currently there has not been a marketing effort to make high school students aware of this opportunity, although there are both high school engineering teachers and high school students enrolled in the class. Once these kinds of partnerships are established, there may need to be modifications to the course to better support this demographic of students. As more students pursue credit for this course, the retention and success of these students as they matriculate into an on-campus program will also need to be evaluated.

Conclusions

In this paper, a MOOC based Introduction to Engineering course was described and the development process was documented. Information regarding the implementation of this course and insights drawn from this first offering of the course were described. While the course effectiveness results that were presented are still preliminary, the course was successfully offered and changes were made to the course based on feedback given by the students. Scalability issues have been addressed and the course is capable of accommodating many more students as the demand dictates. The financial feasibility of such a course is still a question for debate, but the potential to open up first-year studies to anyone around the world makes this an interesting experiment in distance education.

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Appendix

Table 4: Course Content Breakdown

Week	Overall Topic	Titles of Units
1	What is Engineering?	What is Engineering? What do Engineers Do?
		The Engineering Design Process
		Problems Engineers Can Solve
2	Problem-finding and Definition	DeVILS Project Introduction
		How to Identify Opportunities for Design
		Needs Assessment and Problem Definition
		Defining Requirements and Criteria
		Analytic Hierarchy Process (AHP) Analysis
3	Developing a Successful Design Solution	Imagining Possible Solutions
		Making Design Decisions
4	Autodesk Fusion 360 Tutorial	Overview of Autodesk Fusion 360
		Autodesk Fusion 360 Basics
		Create a Nametag
		Modelling a Robot
		Modelling a Desk lamp
5	Technical Communication	Technical Communication Overview
		Oral Presentations

		Technical Writing
		Formatting Figures and Equations
6	Disaster Relief Project Introduction	Project Introduction/Refresh
		Opportunity Identification
		Airplane Simulator/Basics of Aircraft Design
		Project Planning
7	Modeling	What is a Model?
		Orthographic Drawing
		Predictive Modeling
		Aircraft Wing Design
8	Designing for a Purpose	Designing for a Purpose: Human Centered Design
		Design Approaches for Complex Systems
		Designing the Interior of an Aircraft
9	The Design of Wings: An Overview of Structural Analysis	An Overview of Structural Analysis: Important Concepts
		Modeling Wings as Beams
		Wing Structural Analysis Simulation Introduction
10	UML Descriptive Modeling	Automation Overview
		Use Case Diagrams
		Sequence Diagrams

		Activity Diagrams
11	Arduino Programming	A Simple LED Circuit
		Arduino Overview (in 123d)
		Writing Simple LED Program
		Writing an Advanced Controlled Program
12	Finalizing Your Design	Making Final Design Decisions
		Troubleshooting Strategies
13	Acceptance Testing	Importance of Testing
		Parts of a Testing Procedure
		Writing a Simple Test
14	Financial Analysis	Basics of Financial Analysis
		Cash Flow Diagrams
		Financial Decision Making: LTW and ROI
		Financial Analysis of an Airplane (Example)
15	Wrap-up: The Future of Engineering	Final Exam Preparation
		What Have You Learned?
		Looking Forward: What's Next?