

A Multidisciplinary MOOC on Creativity, Innovation, and Change: Encouraging Experimentation and Experiential Learning on a Grand Scale

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Darrell Velegol attended West Virginia University for his BS in Chemical Engineering, and he earned his PhD in Chemical Engineering at Carnegie Mellon University in 1997 working with Professors John L. Anderson and Stephen Garoff. In 1998 Velegol won the Victor K. LaMer Award of the American Chemical Society for the best PhD in the field of Colloid & Surface Science. He continued with a post-doc in the Center for Light Microscope Imaging and Biotechnology at Carnegie Mellon, working under Professor Fred Lanni of the Biology Department. In June 1999 Velegol joined the Department of Chemical Engineering at Penn State, where he was promoted to Associate Professor in 2005. Velegol won an NSF CAREER Award in 2000, and has continued to be funded by NSF, DOE, EPA, PRF, the Air Force, and other agencies for his work with colloidal forces, colloidal assembly, electrokinetic flows, and colloidal motors. His research investigates the fabrication of colloidal assemblies and devices, with a specialty in understanding the interparticle forces and sorting processes. His research group uses a wide range of experimental and modeling approaches. In 2009 Velegol was promoted to Full Professor at Penn State. For his work in experimental and theoretical problems in the dynamics of complex colloidal particles, Velegol was elected a Fellow of the American Association for the Advancement of Science in 2011, and appointed as a Distinguished Professor at Penn State in 2012. He is a member of ACS, AIChE, AAAS, and ASEE. More recently, he has engaged in studying the "physics of community", pursuing questions in learning, creativity, motivation, trust and deceit, courage, and other social science ideas using results from physics, chemistry, biology, and chemical engineering. In 2011 he published a book, *Wild Scholars*, available through amazon.com, and he seeks to impact education from grade school to college. In 2013, he published a book *CENTER*, which details six practices needed to go from your passions and purposes, to making a change in the world. In Fall 2013, he is teaching a MOOC called "Creativity, Innovation, and Change", which has over 120,000 students.

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Abstract

This paper reports on the design, development, and delivery of a multidisciplinary MOOC (Massive Open Online Course) on creativity, innovation, and change. Our aim was to provide students with concepts and tools to help them realize their creative potential, support innovative behavior, and promote positive change in the world. Details of the course structure and its operations are discussed in relation to essentials of problem-based learning, patterns of student engagement, extent of experiential learning, and the use of social media. We also review the demographics of our 124,000+ MOOC students, who represented nearly 200 countries and over 35 academic disciplines, as well as statistics related to their enrollment, retention, and course completion. Finally, we discuss the implications of MOOCs for engineering education in both face-to-face and online formats, our recommendations for the development of MOOCs, the challenges and limitations of our work here, and our plans for future research in this domain.

1. Introduction

Although new on the educational scene, Massive Open Online Courses (MOOCs) are already the subject of great debate in terms of their educational value, academic rigor, financial sustainability, and role in higher education^{3,4,11,13,14}. They also take on many different forms in terms of their teaching/learning approaches, although most focus primarily on straightforward content delivery, with their students assessed via traditional online quizzes and exams. MOOCs with an experiential and/or process-oriented focus are less common; interestingly, those that do exist often have engineering and/or design at their core^{1,10}.

In this paper, we discuss our development and delivery of a multidisciplinary, process-oriented MOOC on creativity, innovation, and change, designed to encourage experimentation and experiential learning in balance with content mastery. One aim in creating such a course was to provide students with concepts and principles embedded in a creative problem-solving process that would enable them to realize their creative potential and learn to innovate within a self-directed learning environment. Another aim was building a global creativity community, connecting learners around the world with a passion for change. These topics and skills are of particular importance to engineering students as they learn to create our technological future, but they are equally important to students in other disciplines as they solve the most pressing problems in their respective domains. The integration of engineering and non-engineering expertise may, in fact, lie at the heart of solving some of our greatest challenges today.

In the following sections, we describe the essence of our MOOC and explore several key questions related to our experience as its instructors. First, to what degree and in what ways did students engage in our experiential, process-oriented MOOC? Second, to what extent did we achieve the key aims of our course – i.e., encouraging experimentation and experiential learning among our MOOC students? Finally, we consider the benefits and challenges of our approach and the potential for blending process-oriented MOOCs with face-to-face engineering courses.

2. Background and Course Context

2.1 cMOOCs, xMOOCs, and MOCCs

Although MOOCs might be said to come in one size (some form of “extra-large”), they come in more than one shape. Welsh and Dragusin¹³ describe current MOOCs as being one of two types:

- **cMOOCs** – the first generation of MOOCs (2008): These MOOCs focus on knowledge co-creation by harnessing the power of social media and interaction with peers, adopting a connectivist learning approach. Students’ creativity, autonomy, and networking are encouraged; they are expected to add to and enrich the course content.
- **xMOOCs** – the second generation of MOOCs (2012): These MOOCs focus on more traditional interaction with fixed content, centralized discussion forums, and automated or peer-graded evaluation, adopting a behaviorist learning approach. Students are expected to master what they are taught without adding substantially to the course content.

In both cases, these MOOCs are typically offered to students free of charge, unless a student wants verification that he or she was the person who completed a particular MOOC. For this service, students pay a small fee (e.g., \$50) to have their work/performance confirmed by MOOC platform personnel using webcam photos and digital forensic techniques, such as typing pattern recognition (see, e.g., Coursera’s Signature Track option²).

Our MOOC was designed as a combined cMOOC-xMOOC with both connectivist and behaviorist characteristics, delivered at no cost to students unless performance verification was desired. Recently, a number of universities have begun experimenting with the possibility of offering massive online courses for college credit. Sometimes known as **MOCCs** (Massive Online Credit Courses), these courses are not free to students. Instead, universities charge a fee (e.g., hundreds of dollars) for the instruction, typically delivered in an xMOOC format, and students receive college credit if they pass the course (e.g., pass an appropriate final exam).

2.2 MOOCs and Problem-Based Learning (PBL)

As noted above, one of our aims in developing our MOOC was to help students realize their creative potential and learn to innovate within a self-directed learning environment. This aim led us to consider problem-based learning (PBL) as an appropriate pedagogical framework for instruction. Problem-based learning (PBL) has been used successfully for nearly 40 years and continues to gain acceptance in multiple disciplines, including engineering. In his overview of problem-based learning, Savery identified a set of ten “Generic PBL Essentials”, as follows⁹:

1. **Personal Responsibility.** Students must have the responsibility for their own learning.
2. **Ill-structured Problems.** Problem simulations used in problem-based learning must be ill-structured and allow for free inquiry.
3. **Integrated Learning.** Learning should be integrated from a wide range of disciplines or subjects.
4. **Collaboration.** Collaboration is essential.
5. **Reanalysis and Resolution.** What students learn during their self-directed learning must be applied back to problems with reanalysis and resolutions.

6. **Personal Reflection.** A closing analysis of what has been learned from working with a problem and a discussion of the concepts and principles involved are both essential.
7. **Self- and Peer Assessment.** Self- and peer assessment should be carried out at the completion of each problem and at the end of every curricular unit.
8. **Real-World Activities.** The activities carried out in problem-based learning must be those valued in the real world.
9. **Exams Measure PBL Progress.** Student examinations must measure student progress towards the goals of problem-based learning.
10. **Pedagogical Base.** Problem-based learning must be the pedagogical base in the curriculum and not part of a didactic curriculum.

We believe that MOOCs can be designed to deliver these PBL essentials effectively, and in some cases, there may even be advantages in using a MOOC format. For example, with a typical MOOC class size in the tens of thousands and with students globally dispersed, independent responsibility for one's learning is essential. Likewise, the diversity of students present in most MOOCs provides opportunities to collaborate across wide physical and cultural boundaries, which is generally not possible in traditional face-to-face courses. In addition, as multiple modes of electronic communication (e.g., video conferencing) become more commonplace, students learn to problem solve and collaborate in ways that are frequently used in industry.

On the other hand, the same MOOC characteristics make other PBL essentials – such as peer assessment at the completion of each problem and student examinations that measure student progress toward PBL goals – more challenging. Some of Savery's other PBL essentials relate to specific course content (e.g., integrated learning from a wide range of disciplines, activities with real-world value), which may or may not be present in a particular MOOC. Fortunately, our MOOC's subject matter made many of these content-related essentials fairly straightforward to deliver, a topic we will discuss later in this paper.

2.3 An Institutional Perspective

Academic institutions have taken a range of approaches to MOOC adoption in these early years, from ignoring them completely to investing considerable sums of money in their development. At Penn State University, home of the CIC MOOC, the administration has elected to “dip their toes in the water” at this time – i.e., testing the feasibility and efficacy of MOOCs through small to moderate investments in a decentralized fashion (i.e., with sponsorship at the College level). Within this context, our MOOC (which was sponsored by the College of Engineering) was chosen to be one of five initial MOOC offerings when Penn State contracted with Coursera in 2013. In particular, it was chosen to represent a highly generalized MOOC that would appeal to a large number of students across multiple disciplines, cultures, and other demographic sectors.

3. The Design of an Experiential MOOC on Creativity, Innovation, and Change (CIC)

Our MOOC was formulated as a multidisciplinary course that was cross-listed in the Coursera platform under information technology, design, business, management, engineering, education, and the social sciences (<https://www.coursera.org/course/cic>). Our combined experience teaching and researching creativity and innovation-related topics is extensive (60+ years between the three core instructors in both face-to-face and online venues). We decided to integrate our collective

expertise into a single process-oriented course that would address the need for accessible creativity, innovation, and change instruction in the world culture. Many principles of creativity, innovation, and change are universal, although application of those principles may vary across knowledge domains.

The course was first formally conceived in January 2013, with a preliminary course design proposed in February and a course syllabus constructed by May. Video production (the most time-consuming portion of the course development) and other content creation occurred over the summer (June – August), and the course was delivered in September/October 2013 over an 8-week period (with a 2-week extension for final assignment submissions). Our team was composed of three core faculty in different engineering fields (chemical, environmental, and mechanical/design), a faculty member from theater (who also served as an acting coach), a team process coach (psychology), an instructional designer, several university technical staff who liaised with Coursera and managed contractual issues, and a mix of graduate and undergraduate students from engineering and education who assisted as staff with many tasks along the way.

3.1 Levels of Student Engagement

Student engagement and retention are major issues in the current MOOC context⁴. In particular, the low percentages of enrolled students who complete MOOCs (i.e., earn certificates) are a subject of much debate and conjecture. Our course was designed to support three levels of student participation, which correspond generally to:

1. Students who occasionally interact with the course (they are “just visiting”);
2. Students who digest the video/reading material and complete the exercises and quizzes;
3. Students who digest the video/reading material, complete the exercises and quizzes, and complete a course project.

In our MOOC, students in the first category were called “**Tourists**”, while students in the second and third categories were called “**Explorers**” and “**Adventurers**”, respectively. To earn a course certificate, students were required to complete an Explorer track (standard certificate) or Adventurer track (certificate with distinction). Our main aim in defining these three levels of engagement was to encourage students to participate to whatever extent they desired and could manage, enabling them to determine their own level of commitment based on their personal schedules and resources. Early MOOC research tells us that the vast majority of MOOC students are adult learners^{3,14}, and we hoped to increase student engagement by allowing these busy learners to remain involved, even if they did not earn a certificate of completion. That is, rather than worrying only about the “drop out” rate in our course, we also wanted to provide as many ways as possible for students to “drop *in*”, enabling our MOOC to have value beyond a simple completion rate.

3.2 Course Structure and Content

The course lessons were delivered over 8 weeks based on the timeline/syllabus shown below (see Table 1), with new material released each Sunday. Students were expected to spend 6-8 hours per week on their coursework (watching videos, reading, completing exercises, engaging in projects, etc.) and were given two weeks to complete each assignment (a soft deadline after one week, a hard deadline after two weeks).

Table 1. CIC MOOC Timeline/Syllabus

Schedule / Tasks	Explorers <u>and</u> Adventurers must do this:	Adventurers must <i>also</i> do this:
Week 1 9/1-9/7	Uncovering Your Creative Identity - Week One Content Quiz - Complete at least 1 Exercise & Reflection Survey	
Week 2 9/8-9/14	Idea Generation - Week Two Content Quiz - Complete at least 1 Exercise & Reflection Survey	Project Phase 1: Exploration Statement & Reflection
Week 3 9/15-9/21	Idea Evaluation - Week Three Content Quiz - Complete at least 1 Exercise & Reflection Survey	
Week 4 9/22-9/28	Creative Collaboration - Week Four Content Quiz - Complete at least 1 Exercise & Reflection Survey	Project Phase 2: Design Statement & Reflection
Week 5 9/29-10/5	Research - Week Five Content Quiz - Complete at least 1 Exercise & Reflection Survey	
Week 6 10/06-10/12	Metrics - Week Six Content Quiz - Complete at least 1 Exercise & Reflection Survey	Project Phase 3: Experimentation Statement & Reflection
Week 7 10/13-10/19	Experimentation - Week Seven Content Quiz - Complete at least 1 Exercise & Reflection Survey	
Week 8 10/20-10/26	Synthesis of Creativity, Innovation, and Change - Week Eight Content Quiz - Complete at least 1 Exercise & Reflection Survey	Project Phase 4: Application/Reflection Statement & Reflection

Each lesson was structured around the following online components:

- Videos
- Readings
- Quizzes
- Exercises
- Projects
- Reflections
- Discussion forums
- Idea Cloud

In addition, different types of social media (e.g., Facebook, Google+, LinkedIn, Twitter) were used to enhance student collaboration and communication outside the Coursera platform. We will comment briefly on each course component below.

Videos and Readings

The videos and reading materials for the course were separated into *core content* and *supplemental content*. Core content videos and readings were produced by the three lead instructors, while supplemental content was gathered from invited guests (e.g., our acting and process coaches, colleagues at other institutions, other outside experts) and publicly available resources (e.g., YouTube videos, open source articles). The core content was based on three subject themes, as illustrated in Figure 1 and defined below:

1. Intelligent Fast Failure^{7,8}
2. Creative Diversity^{5,6}
3. CENTER¹²

By integrating these three themes, we aimed at developing change-focused mindsets for creativity and innovation in our MOOC students: Creative Diversity to recognize that everyone is creative in different ways, CENTER to guide the process of turning passion and initiative into possibilities, and Intelligent Fast Failure to actuate change through frequent experimentation.

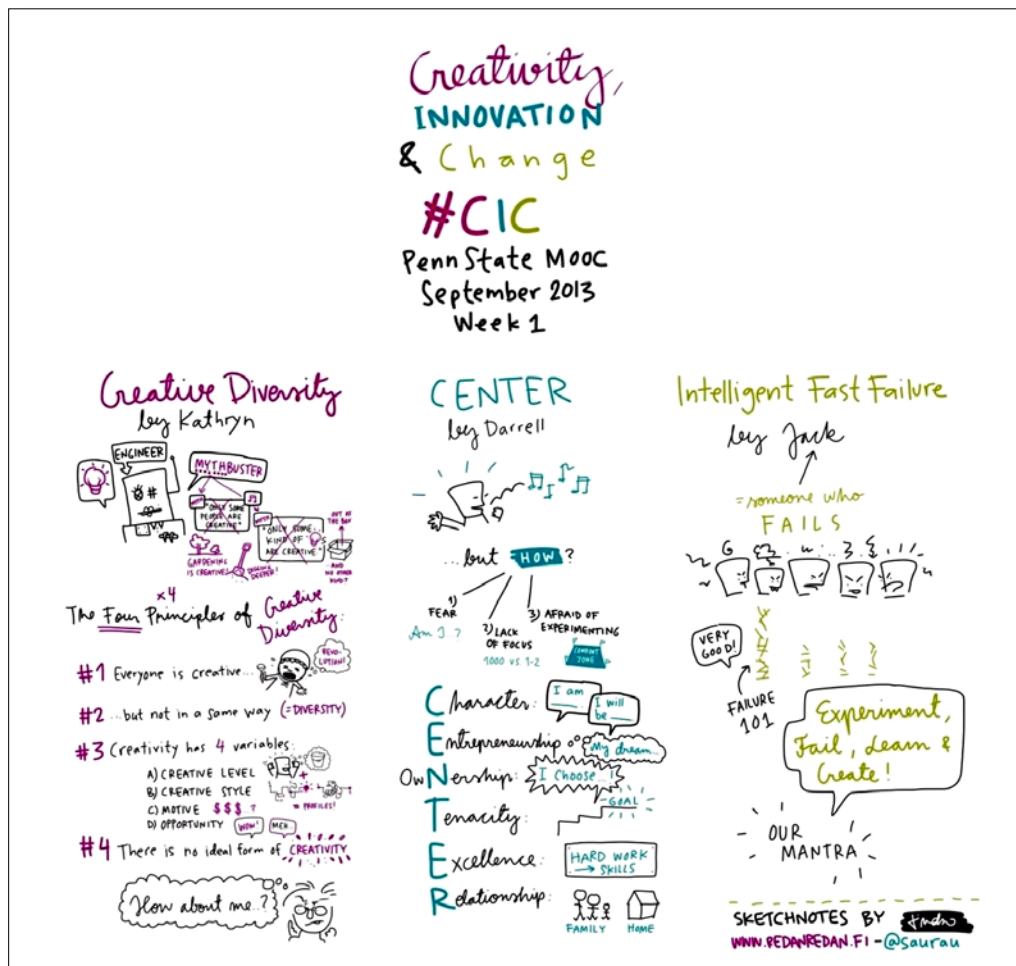


Figure 1. One CIC MOOC student's visual summary of the three course themes

Briefly, **Intelligent Fast Failure** (IFF) focuses on the “rapid prototyping” of ideas, products, and processes, so that “rapid and smart” trial and error through experimentation becomes a significant source of information and knowledge, providing the foundation for application and design^{7, 8}. As illustrated in Figure 1, the principles of IFF were originally formulated in a resident engineering freshman seminar class (aka “Failure 101”) at Penn State, in which students were encouraged to fail early, quickly, and frequently, both to acclimate themselves to failure and to develop a personal process for learning from their failures. Within the MOOC context, these principles were translated into experiential exercises that encouraged students to experiment with previously untested ideas, record their failures, reflect on what they learned from those failures, and create new solutions in response (“Experiment, Fail, Learn & Create!”).

As shown in Figure 1, **Creative Diversity** (CD) is based on four principles, beginning with the fundamental assumptions that all human beings are creative, but not in the same ways. These assumptions conflict with the popular view of creativity, which often sets apart certain people (e.g., artists, writers) and/or certain kinds of ideas (e.g., “out of the box” ideas) as “truly” creative, while others are not. The four principles of Creative Diversity “bust these creativity myths” by defining four key variables to distinguish the creativity of one person from another, namely: creative level (your potential and manifest cognitive capacity), creative style (your cognitive preference for structure), motive (the things that motivate you – e.g., financial gain, striving for excellence), and opportunity (what is available and how you perceive it)^{5, 6} – with every combination of these variables valued equally overall, although particular combinations may be more effective in specific situations. In the MOOC context, students completed experiential exercises to help them identify their personal creative profiles based on these variables.

Finally, **CENTER** focuses on six practices that lead students to identify “who they are” and guide them through making choices that enable them to make change. As Figure 1 indicates, these core practices lie in the principles of Character, Excellence, owNership, Tenacity, Entrepreneurship, and Relationship¹². Like Intelligent Fast Failure, CENTER principles and practices help students move past the fear of experimentation by providing a focused and organized approach to exploring one’s core identity and values (Character), choosing and taking responsibility for appropriate goals to support one’s ambitions (owNership, Entrepreneurship), and then establishing a plan for reaching those goals through the necessary skills and relationships (Tenacity, Excellence, Relationship). Within the MOOC context, students were led through experiential exercises for each of the six CENTER practices to map out their goals and strategies for reaching them.

The production of high quality videos was an important feature in our development of the course, so we engaged a faculty colleague in the School of Theater to serve as a scripting and acting coach for our team. Video production (including planning, scripting, rehearsals, and filming) and editing were significant undertakings, requiring considerably more time than we originally anticipated. Most of our core videos were filmed in Penn State’s television studios and edited by professional personnel, which – in combination with the lessons learned from our acting coach – led to very high quality productions. A handful of videos were filmed in smaller university media labs, and these were also quite satisfactory. Learning to be actors (as opposed to “talking heads”) meant that we had to dispense with traditional lecturing (which tends to be relatively unfocused) and carefully script what we wanted to say, using effective body and facial movements to make the delivery interesting and compelling to the students. The result was a series of short videos of less than 10 minutes each (most less than 5 minutes), in which we communicated the core of

each principle and/or its application, delivered individually or (more commonly) as a small group discussion among the three instructors.

Content Quizzes

Simple content quizzes were created based on the core video content each week to determine whether or not students understood the material. These quizzes were comprised primarily of multiple-choice questions, which were automatically scored by the Coursera platform software. In addition to questions focused on knowledge mastery, the quizzes also gave students an opportunity to evaluate the quality and usefulness of the core videos through simple evaluative questions (e.g., “Will you be able to integrate the strategies and techniques discussed in this week’s videos in your life and work?”), as well as open-ended feedback.

Exercises and Reflections

Building on the three themes illustrated in Figure 1, a menu of 1 to 4 exercises was offered each week, in which MOOC students were given experiential tasks to perform (e.g., generating ideas, estimating creative styles, creating personal brands, identifying resources for new entrepreneurial ventures, evaluating ideas, devising plans for managing resistance, organizing teams). Some exercises were delivered in text descriptions, while others were introduced through short videos. Following the completion of each exercise, students were required to submit a reflection survey based on their experience with the exercise. In addition to reporting specific results (e.g., “how many ideas did you generate?”), students also answered open-ended questions involving reflections on their learning processes, creative identity, and/or change-related actions (e.g., “what did you learn about yourself while completing this exercise?”). Students were invited to upload images, videos, or other supplemental material they created during the completion of each exercise to represent their results and/or experience, but this was not required.

Student Projects and Reflections

Students who participated at the highest level of engagement (Adventurers) were required to complete a course project, either alone or as part of a team. These projects were self-determined and could be a variation or continuation of an ongoing project (personal or professional), a new idea that resulted from one of the exercises/techniques introduced in the course, or a combination of the two. Projects could be of any length and could extend beyond the 8 weeks of the course – as long as the student’s aim was to generate new ideas, experiment with and prototype those ideas, and initiate positive change as a result.

Students were guided through a creative problem-solving process model with four stages: *Exploration, Design, Experimentation, and Application/Reflection*. A new stage was introduced every two weeks. Similar to the course exercises, students assessed their own project results via a reflection survey, which included a description of their progress, optional media presentations, and reflections on what they learned. Peer review was also offered and implemented via the course discussion forums. Projects ranged widely in scope, from efforts to engage young people in Eastern Romania to be entrepreneurs, to Malaysian high school students taking the MOOC as part of a chemistry course, to software engineers in India developing computer applications for medical records, to authors in the U.S. finishing book manuscripts, to scientists in Kenya looking at food security for small farms.

Discussion Forums

The Coursera MOOC platform relies heavily on discussion forums for student-to-student and student-to-instructor interaction; MOOC instructors are free to organize the threads in those forums to align with their course structure. We set up a separate discussion forum for each major element of the course (videos, exercises, projects, the Idea Cloud), as well as a general discussion forum, a Professor Digest (for our own reflections), and a forum focused on students sharing their creative journeys. For logistical support, we also set up a forum where students could self-organize study groups, as well as forums to address technical issues, errors in course materials, and suggestions/complaints about the course. The discussion forums served as the main mechanism for peer assessment of projects (for Adventurers), as we will discuss later.

The Idea Cloud

In addition to our own core content, we also posted supplemental writings and videos in a separate section within the MOOC site called the Idea Cloud. Some of the videos were invited guest speakers from our own professional networks, whose expert commentary served as valuable additions to the course content. Other videos from the public domain (e.g., TED Talks) provided related material to enrich the course, such as additional case studies, presentations by recognized experts, and examples of others applying the principles introduced in our course. Each week, a selection of these supplemental writings and videos was posted; each item aligned with or added to our core content in some way. For example, during Week 4 (which focused on Creative Collaboration), three supplemental videos related to team diversity, team formation, and team communication, respectively, were posted in the Idea Cloud. Students were not required to review the Idea Cloud materials, but it was a popular feature.

3.3 A Week in the Life of an Adventurer

While limited space prevents us from describing the MOOC student experience in full detail, we might imagine a typical week for an Adventurer named Jamie. Jamie begins by watching the core videos and completing the content quiz on Days 1 and 2. Jamie also begins a creative exercise on Day 2 and completes the exercise reflection survey several days later. On Day 3, Jamie revisits the project description and works on the next project stage. On Days 4 and 6, Jamie watches the weekly MOOCups (Google Hangouts), in which the professors address student questions submitted through social media. If a project reflection survey is due this week, Jamie completes and submits it on Day 6, after working on the project during the week. If Jamie has some extra time, there are recommended readings to peruse, supplemental videos to watch in the Idea Cloud, and discussion forums to read and post comments in – perhaps some of Jamie’s project results, for example. If Jamie’s peers provide some useful feedback on those results, Jamie can integrate them into the next project phase.

3.4 Use of Social Media

Before the course opened officially, we established web sites on Facebook, LinkedIn, and Google+, as well as a Twitter account, to interface with students who had registered early. We then posted surveys to learn why they registered, their expectations, and backgrounds. From the web site analytics, we learned in which countries they resided as well. As the course design progressed, we posted videos and written materials to elicit student comments, and we also noted how they were communicating with each other. All of this useful information was assessed for

implementation in the course. For example, the concept of the Idea Cloud came from a Google+ student who had taken another MOOC course in which supplemental information was nested in a file and updated from week to week. This co-creation aspect of the course was extremely valuable. When our course went active, the social media sites were humming with discussions and networking to form teams, which helped to synergize the activity levels from week to week.

3.5 Student Interaction and Teaming

In our core videos and readings, we stressed the importance of collaboration across disciplines in enhancing creativity, innovation, and change. Special discussion forums were set up solely to enable students to form or join a team, and we checked these forums frequently, commenting and providing positive feedback to student teams. Google+ and LinkedIn were especially effective in stimulating team formation and interaction, with several thousand students establishing online groups in each case; we checked and interacted regularly with these sites/groups as well. In a small pilot study, we also offered students an opportunity to use Purdue University’s CATME tool (<https://engineering.purdue.edu/CATME>) to form teams to complete a particular course exercise; full details of this pilot study will be presented in a future publication.

3.6 Grading and Assessment

Many of the activities presented in our MOOC were directed at students’ personal creative growth, with others focused on the mastery of core principles related to Intelligent Fast Failure, Creative Diversity, and CENTER. As a result, we made some use of formal assessments (i.e., quizzes), but heavier emphasis was placed on students’ personal learning paths and on building meaningful insights through exercises and projects. We defined a task list for those students interested in earning a course certificate according to the two tracks described earlier (Explorers and Adventurers), as shown in Table 2.

Table 2. CIC MOOC Certificate Requirements

Type of Certificate	Requirements
Standard Certificate (Explorers)	<ul style="list-style-type: none"> • 6 out of 8 weekly content quizzes • 8 weekly exercise reflection surveys (after completing at least 1 exercise per week)
Certificate with Distinction (Adventurers)	<ul style="list-style-type: none"> • 6 out of 8 weekly content quizzes • 8 weekly exercise reflection surveys (after completing at least 1 exercise per week) • 3 of 4 project reflection surveys (after completing each project phase, given every 2 weeks)

All grading was done automatically through the Coursera platform. Content quizzes had traditional “right/wrong” answers and open-ended questions, and were graded accordingly. For the reflection surveys (for both exercises and projects), credit was assigned based on their completion rather than “correctness”, since the experiential exercises themselves did not have right/wrong answers. As a result, students who completed a reflection survey received full credit for the exercise (or project stage), while those who did not complete a reflection survey did not receive credit, even if they had actually completed the exercise.

For the projects, we elected to use the discussion forums as the primary mechanism for peer feedback, rather than the peer assessment process defined by Coursera, in which students rate a small number of projects using an instructor-defined rubric, in exchange for which their projects are rated by other peers. We made this decision based on our desire to encourage peer-to-peer interaction on a large scale and to avoid some of the problematic features of the formal peer assessment process (e.g., biased feedback, cursory feedback), which we hypothesized might be more likely due to the self-defined projects featured in our MOOC.

Inevitably, our choice had its own ramifications – i.e., some projects received a considerable amount of peer feedback, while others received none at all. As a result, in addition to the discussion forum peer feedback approach to project assessment, we are exploring other assessment models as part of an internally funded grant. The first model is a classic “teacher-graded method”, in which an expert – in this case, an instructor – grades a submission; this model has obvious challenges in a MOOC context due to the large number of students. The second model is more of an “Amazon.com” model, in which peers submit a ranking of 1 to 5 stars to represent the overall quality of a peer’s project, along with specific written comments. This method has obvious challenges in terms of over-simplification and subjectivity. Our aim in considering this second model is to explore the boundaries of MOOC assessment strategies in the hope of identifying a middle-ground that is both practical and meaningful. We are still analyzing the results of this exploratory study, which has also led us to reconsider the use of Coursera’s peer assessment process in future course offerings.

3.7 Instructor Feedback

With enrollments in the tens (even hundreds) of thousands, individual personalized feedback to every MOOC student on every assignment is clearly impossible. In a sense, the best one can hope for (as an instructor) is to establish a constant “presence” in the course, so students see that their instructors are engaged with them and the material as it is presented. To address this issue, we turned to social media, the MOOC discussion forums, and virtual meeting technology (Skype, Google Hangouts). In the social media (LinkedIn, Facebook, Google+), we formed or joined student-formed online groups through which we could communicate with smaller numbers of students, although membership in those groups was still in the thousands. Surprisingly, with a few exceptions, our MOOC students did not seek us out via regular email channels during the course, despite the ease with which they might locate us through the university web site, but they did occasionally send us messages via the social media sites.

In addition, we regularly interacted with students in the discussion forums, encouraging them when they struggled, praising them when they succeeded, and diffusing tension when it seemed appropriate (students also took on all these roles themselves). We established one special forum – which we called the Professor Digest – in which we posted our personal observations and reflections throughout the course. These reflections and observations served as both formative and summative feedback, to which students could respond in the student forums. Finally, we recorded and posted weekly online meetings (which we called “MOOC-ups”) of the instructors and other key course staff using Google Hangouts, in which we discussed student questions and comments. Questions came from the discussion forums and from students posting questions in real-time using Twitter, making the MOOC-ups a type of “online office hours”.

4. Results, Observations, and Discussion

4.1 The Numbers: Enrollments, Retention, Completion, and Demographics

Course Enrollments

Registration for the Creativity, Innovation, and Change MOOC began on February 21, 2013, less than seven months before it officially opened on September 1, 2013. In that time, 124,814 students registered for the course, with 25,436 (~20%) of those students enrolling in the week immediately prior to the first official day; we will use 124,814 as our baseline for computations related to engagement, retention, etc., in this paper. Note that students continued to enroll in the MOOC throughout its 8 weeks (there was never a day without new registrations), with an eventual total enrollment of 150,317 students when assignment/quiz submissions were closed on Nov. 7, 2013 (see Figure 2). Note: this timeframe included a two-week extension for the submission of all assignments – a common practice in current MOOCs. The course remained open for video, reading, and forum activity beyond Nov. 7, but no further quiz, exercise, or project submissions were accepted.

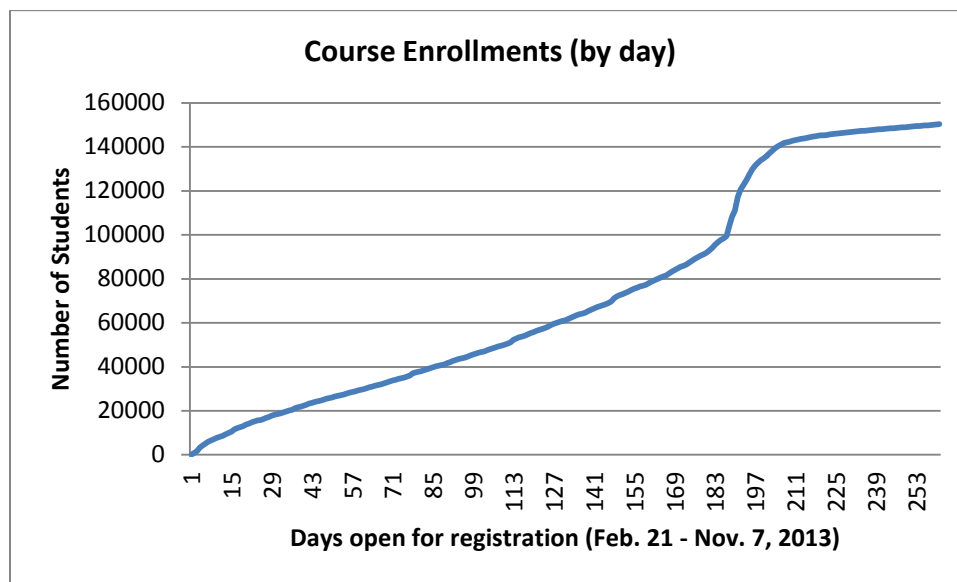


Figure 2. CIC MOOC student enrollments (Feb. 21 – Nov. 7, 2013)

Student Retention

Similar to other MOOCs⁴, not all of the originally registered students logged in to the course to participate. Specifically, 94,788 *unique* students (~76% of the initial enrollments) were active in the course (i.e., logged in to participate at least once), with 13,811 students active in the last week (~11% of the initial enrollments). Figure 3 shows a graph of the number of “active students” from week to week – i.e., students who logged in and participated in the course via core video views or downloads, quiz/exercise/project submissions, and/or discussion forum activity. These numbers do not tell us *which* students were active in which week(s) or which specific course activities attracted their attention; clearly, not all 94,788 unique students were active every week. Further analyses of these activity patterns are on-going.

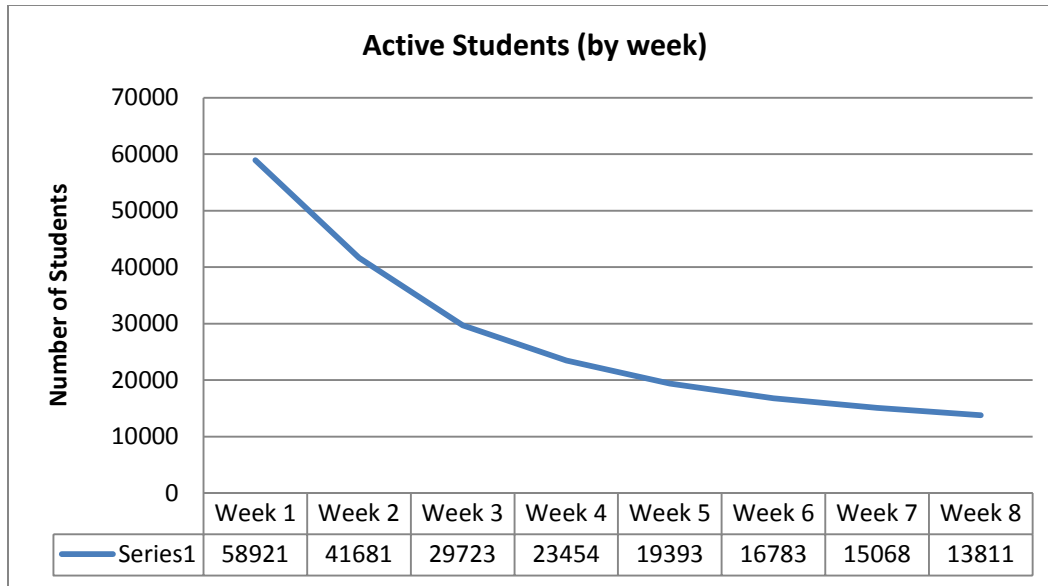


Figure 3. Number of active students by week (Sept. 1 – Nov. 7, 2013).

Course Completion

At the end of the course, 5316 students were awarded certificates of completion (38.5% of students active in the final week, 5.6% of all active students, and 4.3% of original enrollments). These numbers are consistent with completion rates across current MOOCs in general^{4,13}. Of the 5316 certificates awarded in our MOOC, 3821 (72%) were standard certificates (Explorers), and 1495 (28%) were certificates with distinction (Adventurers). These and other related statistics are summarized in Table 3 below.

Table 3. CIC MOOC Completion Rates (Certificates)

Completion Category	Number (%) of certificates	Percent (%) of original enrollments	Percent (%) of all active students	Percent (%) of students active in final week
All certificates	5316	4.3	5.6	38.5
Standard certificates	3821 (72%)	3.0	4.0	27.7
Certificates with distinction	1495 (28%)	1.3	1.6	10.8

Student Demographics

Coursera asks all students to complete a demographic survey when they register for their first course, but this is optional. As a result, student demographic information is often incomplete, and our MOOC was no exception in this regard. Of the 124,814 students enrolled on the first day of the course, 16,945 (13.6%) completed the Coursera demographic survey. We will use those survey results here to discuss the demographics of the students in our MOOC, recognizing that they represent only a portion of the students who participated.

First, the gender split of this sample was essentially 50/50 (8463 female, 8482 male), representing a slight shift from Coursera's overall statistics, which recently showed a higher percentage of male students (~57%) across all of Coursera's offerings¹⁴. Student ages in our MOOC ranged from 11 to 90 years old, with an average age of ~35 years old (which does align with Coursera's general statistics). A total of 195 nations, territories, and principalities were represented in the student body, with 16% of the students of Spanish, Hispanic, or Latino descent. In addition, 63% identified themselves as White/Caucasian, 21% as Asian, 4% as Black/African American, and 1% as American Indian/Alaskan Native; 11% did not answer questions about their race. Approximately 50% of our students identified themselves as native English speakers with respect to writing, reading, and/or speaking.

In terms of educational status, 76% reported having a bachelor's, master's, doctorate, or other professional degree (e.g., M.D.), 4% reported having an associate's degree (academic or vocational), 8% reported finishing some/all of high school, 0.3% reported finishing some/all of primary school, and 0.1% reported having no formal schooling at all. In addition, 18% of this sample reported being full-time students, while 11% reported part-time student status. Among those students who had completed a degree program of some kind, over 35 academic disciplines were represented, underscoring the broad multidisciplinary nature of our MOOC students. Finally, in terms of employment status, 69% of the students identified themselves as employed (including self-employed), 19% were unemployed, 2.5% were retired, 2.3% identified themselves as homemakers, caretakers, or on maternity/paternity leave, and 1.6% reported themselves as unable to work.

In general, these results were consistent with our expectations based on the demographics of students enrolled in the two previous MOOCs at Penn State, although we were somewhat surprised by the very broad age range of our students and by the higher percentage of women participating in the course (compared to other Coursera MOOCs). The number of countries and disciplines represented was also very encouraging.

4.2 Student Engagement

As noted earlier, we were interested in the different ways and degrees to which students engaged in our multidisciplinary, experiential MOOC. The enrollment, retention, and completion statistics reported above show that our MOOC was similar to many others in terms of overall participation; we were also interested in determining which specific course components and which particular kinds of activities students found most appealing and useful. At the time of this writing, we are processing the enormous data files (i.e., millions of entries) downloaded from Coursera that will help us answer these questions in detail, but some preliminary results are available here.

Levels of Student Engagement: Intended vs. Actual

As noted in an earlier section, students were offered three levels of engagement in this course – Tourists, Explorers, and Adventurers – only the last two of which could lead to a certificate of completion. From the statistics reported above, it is clear that the vast majority of our students participated in the MOOC as Tourists (which still provided them with valuable learning opportunities). In a post-course survey (administered through Qualtrics), we asked students to report their intended and actual levels of engagement based on the three levels offered to them; 4642 students completed the post-course survey, with the results as shown in Table 4.

Table 4. Intended vs. Actual Engagement Levels of CIC MOOC Students

Engagement Level	Intended	Actual
Tourist	18%	20%
Explorer	45%	55%
Adventurer	37%	25%

These data suggest that most students who intended to complete the most rigorous (Adventurer) track, but could not do so, reverted back to the middle (Explorer) track, rather than the least rigorous (Tourist) level of engagement. When asked *why* they had not completed all the requirements for the Adventurer track (i.e., quizzes, exercises, and a project), students’ top three reasons were: (i) they ran out of time; (ii) they could not think of a good project topic; and (iii) they could not figure out what to do. Student comments on the social media sites also indicated that the course was run at a “frenetic” pace. Further analysis of these results in combination with the full post-course database from Coursera will be reported in a future publication.

Exercises and Reflections

In terms of the experiential exercises offered in our MOOC, roughly 22,000 unique students submitted over 83,000 exercise reflection surveys. As shown in Figure 4, student participation dropped off significantly in the first two weeks (by 52%), although this does not represent the number of students who read or thought about the exercises – only actual reflection submissions. Interestingly, after Week 3, the decline in student participation in the exercise reflections slowed considerably (to 7% or less in Weeks 5 through 8). Still, more than 4600 students completed at least one exercise in the final week of the course – a number larger than the total number of students any of the MOOC’s instructors is likely to teach in a more traditional fashion across his or her entire career.

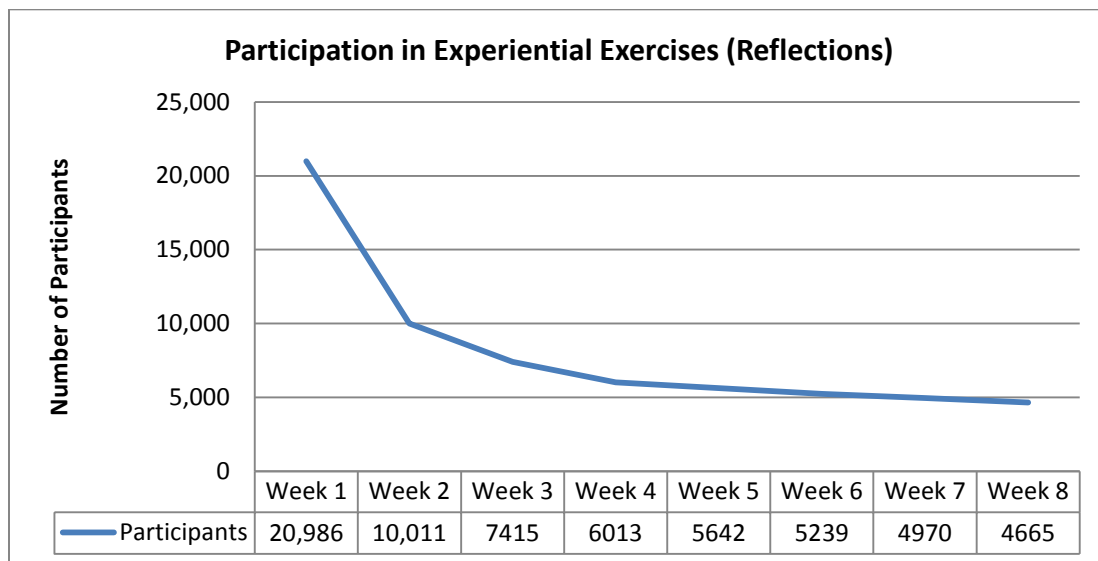


Figure 4. Number of students participating in weekly exercises (reflections)

Projects and Reflections

In terms of the self-defined projects in our MOOC, roughly 4300 students began a project, while approximately 1500 students completed one. Student participation in project reflections showed a similar rate of decline to that seen for the experiential exercises over the first two weeks of the course (also a 52% drop), as shown in Figure 5. Again, the rate of decrease slowed after the first two phases of the project (to 21% and 7%, respectively), showing that project completion became much more likely if a student remained in the course past the 4th week. Note that essentially all students who completed Phase 4 of the project received a certificate of distinction (1495 of 1504).

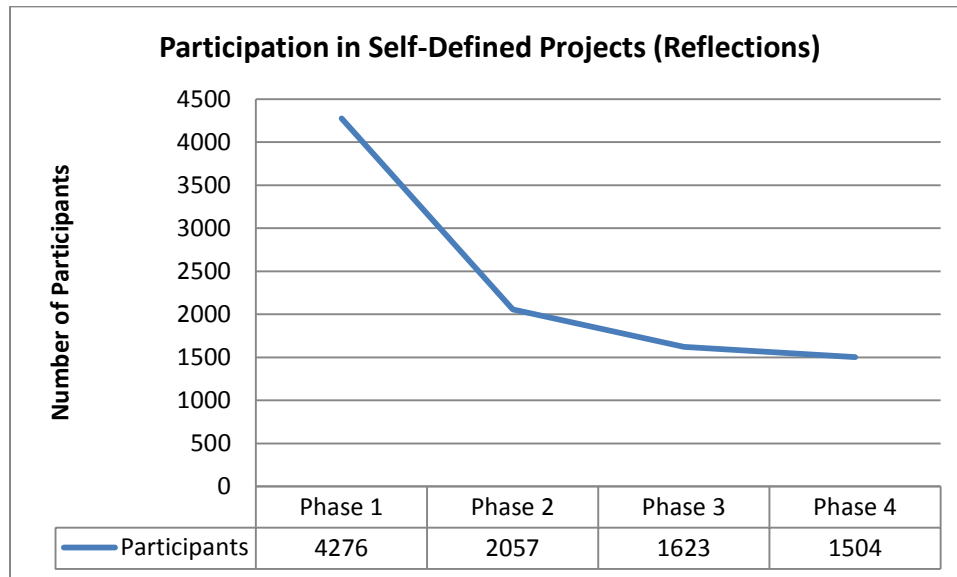


Figure 5. Number of students participating in self-defined course projects (reflections)

As discussed earlier, the (self-reported) primary reasons students did not complete an Adventurer track were related to lack of time and lack of clarity (either in choosing a project topic or in figuring out what to do). We are currently analyzing student outcomes from all four phases of the project to uncover more details about these issues, so they can be addressed in the next version of the course. In particular, we are curious about the scope of the projects defined by our students (e.g., were they too large, too general, or too complex?), as well as places in the project description and instructions that would benefit from better definitions and/or direction. These results will be discussed in a future publication.

Student Interaction, Feedback, and Peer-to-Peer Learning

The primary venues for student interaction, peer feedback, and other forms of peer-to-peer learning in our MOOC were the internal course discussion forums and external social media sites (e.g., Facebook, LinkedIn, Google+, Twitter). Table 5 shows the approximate number of student participants in each of these venues across the 8 weeks of the course. Figure 6 shows the daily pattern of participation by unique students in the course discussion forums as the course progressed. Forum participation remained <1% of original enrollments during the entire course, although this percentage spiked during the first week of the course. This suggests an important opportunity in future offerings of this MOOC to improve participation, student self-organization, and peer-to-peer feedback on their exercise and project results.

Peer feedback is a critical component to enable iterative problem solving in large classroom settings (both face-to-face and online), and this element of our MOOC will need refinement (and possibly reinvention) in the future. We have not identified the most effective answer for this challenge yet, but we plan to compare multiple peer feedback and assessment mechanisms in the next version of this course – including the Coursera peer assessment mechanism, restructured discussion forums, an Amazon.com-like rating system, and other strategies.

Table 5. Student Interaction Venues and Participation (unique students over all 8 weeks)

Interaction Venue	Number of Student Participants (approx. totals)
Course Discussion Forums	6,000
Facebook	11,000
Google+	2,400
LinkedIn	2,000
Twitter	2,500

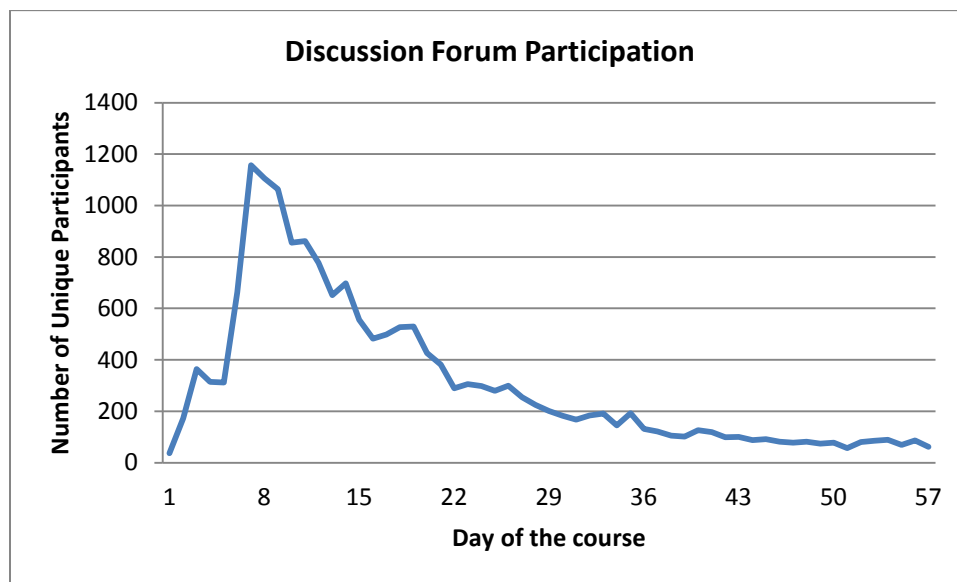


Figure 6. Number of unique students participating in the discussion forums (per day)

General Observations on Student Engagement

Overall, the levels and types of student engagement in this MOOC are consistent with other MOOCs of similar size. All three levels of engagement (Tourists, Explorers, and Adventurers) were represented here, but as might be expected, the vast majority of the students participated as Tourists, who (we hope) benefited through whatever knowledge and insight they gained while they were engaged in the course. Still, we had anticipated that more students would attempt self-defined projects – even if they did not complete them. As noted earlier, we are seeking ways to provide more/different guidance in identifying viable projects, as well as ways to streamline the

course activities so that the requirements for certificates are more manageable for working adults.

One unexpected yet pleasant result was the number of students who indicated how the course changed their lives in positive ways. We received dozens of comments like these:

“It has been a great experience to learn so much from you. You are great teachers and have sincerely been instrumental in bringing a big change in my life. I feel blessed to have enrolled for CIC and connect with you. The course was very interesting. I have had a better understanding of people and the way they handle various situations, as now I am able to relate it to creative diversity. The applicability of this course in personal and professional lives is what made learning more fascinating. Thank you, teachers, from the bottom of my heart!”

(~Female student from India)

“Hi, Professor! I am excited to find you in LinkedIn. Am really happy for the impact the CIC has made in my life. I can understand well how creative I am and further, I now carry an idea journal wherever I go. Over the past few days, I have been able to capture more than 7 ideas which I can use as a basis to start a business and also for my bachelors' project, which I will start soon. Thank you very much and am really grateful for the great job you are doing.”

(~Male student from Kenya)

Our broad review of student participation in the MOOC exercises, projects, and discussion forums is useful as a first general estimate of student engagement in this course, but it also raises questions that can only be answered through further analysis. For example, some of our exercises had a particularly strong emphasis on experimenting with ideas; we plan to analyze the students' responses to those exercises to determine what forms their experimentation took and the extent to which students changed their views of “failure” as a result. Text analysis of students' exercise and project reflections will also provide a deeper view of their individual approaches to experiential learning – among many other insights. It is safe to say that the analysis of this course and the evaluation of our approaches will be a long and rich learning experience.

4.3 Achieving Our Key Aims

With so many data still to process and analyze, it is difficult now to quantify how well we achieved the key aims of our MOOC – i.e., encouraging experimentation and experiential learning. What we can say at this time is that it is possible (and rewarding) to design and deliver a process-oriented, multidisciplinary MOOC with a focus on experimentation and experiential learning – and that students of all ages, from many cultures, disciplines, and educational levels, find such an approach appealing and useful.

In addition, we can set the course, its features, and its outcomes against Savery's General Problem-Based Learning (PBL) Essentials⁹ and evaluate how well our course supported problem-based learning in this context. In Table 6, we provide a list of Savery's PBL Essentials, along with course features and other evidence related to each one; we then provide a letter grade (based on our own self-assessment) to indicate how well we believe we delivered each of these essentials in our MOOC's first offering.

Table 6. Self-Evaluation of Problem-Based Learning in the CIC MOOC (using Savery’s PBL Essentials)

PBL Essential	Supporting Course Features / Evidence	Grading Ourselves
Personal Responsibility	The entire course structure requires and supports independent learning and individual responsibility for that learning.	A+
Ill-Structured Problems	Both the weekly exercises and the course projects were designed as open-ended, ill-structured problems that required and supported free inquiry.	A
Integrated Learning	Principles of creativity, innovation, and change were presented in a general, multidisciplinary fashion, with examples from both technical and non-technical subjects. Students from over 35 academic disciplines participated in the course.	A
Collaboration	While collaboration was encouraged in the course, the mechanisms and guidance for enabling and supporting that collaboration were insufficient. This is a key area for future improvement.	C
Reanalysis and Resolution	Students were encouraged to apply their learnings from the exercises to the course projects, and vice versa. The reflection surveys will require redesign to improve the tracking of students’ reanalysis to their chosen problems.	B
Personal Reflection	Personal reflections at the end of every exercise and project phase made this a key component of the course.	A
Self/Peer Assessment	General self-assessment for every exercise and project phase is a good start, but this self-assessment needs to be strengthened. Peer assessment was not effective and needs to be revisited and improved.	B-
Real-World Activities	The stages and techniques of the creative problem solving process on which this course is based (e.g., idea generation, idea selection, experimentation) are highly valued in the real world.	A
PBL Exams	Quizzes focused primarily on content mastery at a very basic level. This is a key area for future improvement.	C
Pedagogical Base	While problem-based learning was implicit in all aspects of the course, it needs to be even more explicitly addressed in the next offering.	B

As shown in Table 6, we believe that some aspects of our MOOC supported Savery's PBL essentials very well (e.g., personal responsibility, ill-structured problems), while others were less effective (e.g., self/peer assessment, PBL exams). For example, while the traditional lecture format we are trying to move away from in face-to-face classes is often overdone in MOOCs, our course used only short videos to introduce concepts and examples; we then moved quickly to personal application through exercises and projects. These features encouraged independent learning and personal reflection. On the other hand, collaboration among students was not organized effectively (given the limitations of our own creativity in using the platform!), and we must develop new solutions for our next course offering. We will revisit these aspects of the course in the upcoming months as we enter our own MOOC ("CIC 2.0") redesign phase.

5. Implications for the Engineering Classroom: Face-to-Face, Online, and Beyond

In designing, developing, and delivering this MOOC, our face-to-face and other "traditional" online teaching practices have been affected in many positive ways as well. The scripting and acting skills we learned for the purpose of crisp, concise video lecturing have helped us streamline our in-person presentations of material, including technical engineering topics. The videos, experiential exercises, projects, and associated reflections from the MOOC are being repurposed for use in face-to-face and online for-credit courses, with the added benefit of hundreds (even thousands) of examples and case studies now on hand. Lessons learned from the MOOC discussion forums have informed our redesign of discussion forums in traditional online courses – and the list goes on. With the continued development of new learning technologies and online pedagogies, we see MOOCs as powerful laboratories for learning about learning on a grand scale. What is more, many of our MOOC students were actively engaged in discussions about their own learning within the context of the course itself (e.g., through external blogs), leading to even more insights (for them and for us).

As a specific application of our MOOC learnings in the face-to-face classroom, we will be blending the archived MOOC material with a first-year seminar course and a master's level course (both in engineering) in several studies of the "flipped classroom" approach within the next year. In flipped classrooms, students digest core course material at home through video lectures and online readings, returning to the face-to-face classroom for hands-on application of that material in collaboration with classmates and the course instructor. In other words, "lectures" are delivered at home, and "homework" is done in class in a "flipped" configuration. The results of these studies will be shared in future publications.

In looking at the future development of MOOCs in general, our current recommendations center on blended approaches like those described above, as well as new modes of assessment based on competencies – such as badging. MOOCs will neither solve all the instructional and strategic problems of the academic world, nor will they make all traditional academic approaches obsolete. MOOCs are, in effect, a new learning "technology" with great possibilities, and like all new technologies, their benefits and flaws will not be clear until they have been used and vetted across many different contexts and situations. Our work here represents just one step in that process.

6. Challenges, Opportunities, and Future Work

Our approach to multidisciplinary engineering education in a MOOC clearly has many benefits *and* many challenges. The multidisciplinary content of creativity, innovation, and change was appealing to a large number of diverse learners from around the world, representing a wide range of disciplines and cultures; many of our students were also well-educated and highly motivated. This created a tremendous opportunity to showcase our institution to a wide variety of individuals, including prospective U.S. and international students and their families, who might not have considered it otherwise. While it is too early to make conclusions about the conversion of our MOOC students to traditional students at our institution, university officials are seriously considering the role of MOOCs in outreach and recruitment.

Critics of our MOOC might reasonably say that the decline in participation by those who enrolled in it paints a much less rosy picture than our self-assessment indicates. We agree that retention in our MOOC is a concern that must be addressed if it is to remain viable, while noting that these patterns of declining engagement are typical across MOOCs today⁴ (and the focus of much research interest). In other words, such patterns are characteristic of most (if not all) MOOCs, rather than a weakness of our MOOC in particular. In addition, there is anecdotal evidence that suggests that MOOC students may view success differently than traditional students – i.e., a certificate of completion is of less concern to many of them, particularly the many students with college degrees, than learning specific items of interest from within a course and then moving on. The fact that 13,811 students were active in the last week of the course, while only 5316 received certificates, suggests that students engaged in our MOOC for more reasons than one. At present, we are comparing the activity of students who earned a certificate of completion (“certificate earners”) with those who remained active throughout the course (“continuously active”) to see if we can gain insight into these different motivations and behaviors.

Delivering process-oriented material with an experimental component has its own specific challenges in a MOOC setting. Unlike a face-to-face, process/experiment-oriented course, in which an instructor can be present to observe if and how students move through the process and related experiments, MOOC instructors can only observe the results of their students’ experimentation *ex post facto*. As a result, greater reliance must be placed on student reflections and other forms of self-reporting – all of which must be carefully designed to elicit information that helps the instructor track the student’s actual experience. Ideally, these self-reports would be monitored while the MOOC is underway, so instructors can guide students appropriately, but the large numbers of students (even with attrition) makes this approach infeasible in real-time (except, perhaps, for small random samples).

Nevertheless, these challenges are balanced by new opportunities as well. Because MOOC educators can readily collect data from very large samples with wide subject diversity (whether it is data on process-oriented learning and student experimentation or some other kind of data), the entire process of educational research can be accelerated to some degree. Indeed, when viewed as educational laboratories in their own right, MOOCs present a powerful opportunity to investigate multiple hypotheses simultaneously on a compressed timescale – keeping in mind, of course, that the data cleaning, filtering, and analysis will be slower due to the same size effects!

Ultimately, MOOC research requires a shift in thinking in terms of research design, as well as new skills in appropriate technical subjects, such as data mining.

Considered from a pedagogical perspective, courses with a wide array of open-ended topics (like creativity, innovation, and change) require sufficient scaffolding (i.e., tailored support provided during the learning process to help students achieve their learning goals¹⁵) for learners to navigate and apply those topics effectively. In that regard, we have room for improvement in our MOOC. In particular, we are currently analyzing the extensive data collected by Coursera to determine which course activities were most/least effective, where additional scaffolding is required, and recommendations from MOOC students on how activities might be improved. Streamlining the weekly exercises and supplemental material, providing more effective mechanisms for collaboration, revisiting the notion of content mastery (e.g., quizzes), improving the course project framework, and reframing peer and self-assessment are all priorities in our redesign of “CIC 2.0”. In addition, we are planning to add the entrepreneurial mindset to the course, especially in conjunction with students’ self-directed projects.

From a personal point of view, the principles and practices presented in this course have the potential to stimulate life-changing experiences. Once a student embraces the reality that he or she is creative, and then learns how to use his/her unique qualities to innovate, a new universe of possibilities opens up – to change oneself, one’s local community, and beyond. As instructors, we too were changed in powerful ways by this course, as we were exposed to the diverse cultures of the world. That exposure – and the responses of the students – helped us to realize that in striving to create and innovate, we can discover universal commonalities. We hope that our contribution continues to fuel the students’ insights and aspirations, as it has our own.

In closing, we view our first MOOC experience as a “grand experiment” that embodied the principles of Intelligent Fast Failure, Creative Diversity, and CENTER (the three pillars of the course content) and explored the problem-based learning model in a new context. Our failures were not catastrophic, but they were numerous – as might be expected in such a boundary-bending venture. Fortunately, we are confident that by applying these same principles to the redesign of the course, we will demonstrate their value in the real academic world – and find increased success.

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