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Stimulating Creativity in Online Learning Environments through Intelligent Fast Failure

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Abstract

In this paper, we address the stimulation of creativity in online learning environments through our examination of a simple hands-on task aimed at teaching the principles of Intelligent Fast Failure (IFF) in the context of a Massive Open Online Course (MOOC) focused on creativity, innovation, and change. A simple physical "prototyping" exercise involving common household objects was designed and presented to a global community of online learners using the Coursera MOOC platform. Data gathered from the task outcomes and student reflections were analyzed with respect to gender and cultural differences, as well as correlations between the number of attempts/failures and creative performance metrics. Our results show that while the correlation between number of attempts (i.e., failure rate) and creative performance was statistically significant, the relationship was weak. In addition to these and other quantitative results, this research has value for engineering educators as a case study in the evolution, scaling, and transfer of face-to-face experiential learning tasks to global online learning environments.

1. Introduction

The relationship between creativity and failure appears to be a complex one, with scholars debating the positive and negative effects of failure on the quality and the quantity of creative outcomes[6, 7, 12, 13]. Within this context, the concept of Intelligent Fast Failure (IFF) was developed as a teaching and learning tool that demystifies the role of failure by encouraging calculated and well-informed risk-taking and initiative, coupled with mindful examination of each failure to support learning and increased chances of future success[9, 10, 14]. The IFF concept has inspired many derivatives, including Fast Failure, Fast Forward Failure, and Intelligent Failure[14]. In each case, the fundamental elements are similar – i.e., thoughtfully planned actions of modest scale that have uncertain outcomes, are carried out at an accelerated pace, and which take place in environments that permit effective data collection for later analysis.

The application of Intelligent Fast Failure (IFF) has a rich history in face-to-face engineering classrooms, particularly in the context of design and technology-based entrepreneurship[1, 2], but until now, it has not been studied in an online learning environment. With the rise of online engineering programs and courses, including Massive Open Online Courses (MOOCs), the question of how to extend the principles of IFF to these learning environments is an intriguing one. What is the best way to teach IFF principles in a virtual classroom, where students may come from a diverse range of socio-economic backgrounds and contexts? Which types of IFF activities and tasks are most effective? How should these tasks be assessed to ensure the most meaningful practical applications of IFF? In this paper, we address these questions through our examination of a simple hands-on task aimed at teaching the principles of Intelligent Fast Failure in the context of a Massive Open Online Course (MOOC) focused on creativity, innovation, and change[8]. We begin with a description of the MOOC used in this research.

2. Research Context: A MOOC on Creativity, Innovation, and Change (CIC)

2.1 MOOCs and Experiential Learning

Many academic institutions have invested in MOOCs, but the high attrition rates of MOOC students leave those schools vulnerable to criticism about the quality and relevance of their efforts.[11] Yang et al.[18] explored dropout rates in MOOCs and reported that social engagement is one factor that promotes commitment and lowers attrition. The positive impact of active learning in face-to-face instruction of STEM subjects[4] suggests that incorporating experiential learning activities into MOOCs may provide another way to promote commitment and retention, but in practice, the job is not an easy one. MOOCs are generally described as being one of two types: cMOOCs or xMOOCs[17]. In general, cMOOCs adopt a connectivist learning approach and focus on knowledge co-creation by leveraging social media and peer interaction, while xMOOCs take a behaviorist learning approach and focus on more traditional interaction with fixed content, centralized discussion forums, and automated or peer-graded evaluation. The MOOC studied here was designed as a combined cMOOC/xMOOC with both connectivist and behaviorist characteristics. Translating experiential learning activities to fit either type of MOOC environment is challenging for many reasons, including the asynchronous nature of MOOCs, the physical separation of MOOC students and instructors, and underlying resource issues and/or cultural norms that may preclude certain activities in specific countries[19]. While the research described here does not address issues of MOOC attrition or commitment directly, it is an important step in identifying the effectiveness of a particular experiential learning activity, which may then be used in future studies focused on retention in MOOCs.

2.2 Aims of the CIC MOOC

The multidisciplinary Massive Open Online Course (MOOC) at the heart of our investigation – Creativity, Innovation, and Change (CIC) – was designed to encourage experimentation and experiential learning in balance with content mastery within the general content domains of creativity and innovation. As such, it was an excellent testbed for principles related to design thinking, including concept generation, prototyping, and Intelligent Fast Failure[14]. The primary aim of the course was to provide students with general concepts and principles embedded in a creative problem-solving process that would help them learn to innovate and drive social and/or technical change within a self-directed learning environment. Our aim in making the course general was to reach as many students in as many different disciplines as possible, rather than focusing only on engineers or other technical disciplines. Due to the general nature of the course content, there were no recommended prerequisites for the course. Full details about the original course structure and content are provided in Jablokow, Matson, and Velegol's 2014 article[8]; additional details about the course relevant to the current investigation are provided next.

2.3 Intelligent Fast Failure (IFF) and its Role in the CIC MOOC

Intelligent Fast Failure was one of three main themes that formed the core of the CIC MOOC, along with Creative Diversity[8] and CENTER (Character-Entrepreneurship-owNership-Tenacity-Excellence-Relationship)[8], as illustrated by one MOOC student in Figure 1. 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.

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[14]. As shown in Figure 1, the principles of IFF were originally formulated in a resident engineering freshman seminar class (aka "Failure 101") at the University of Michigan, 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!").

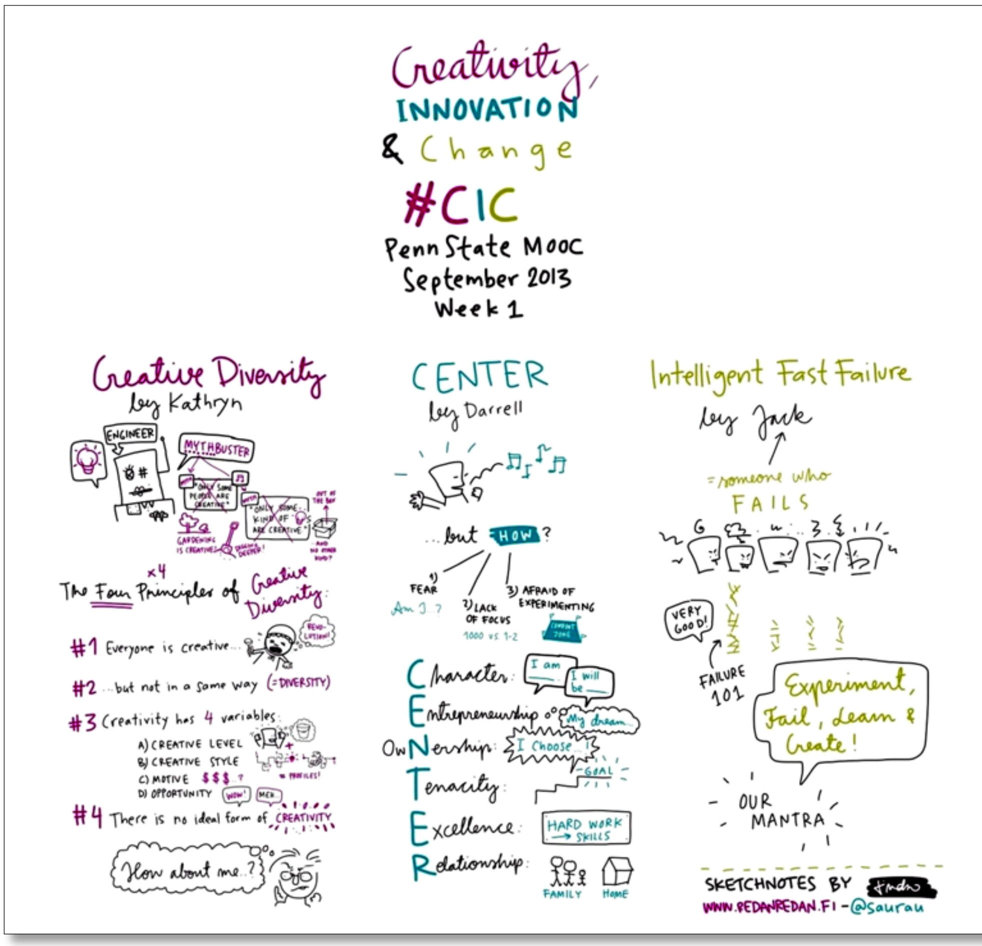

Figure 1. One CIC MOOC student's visual summary of the three course themes

The second theme, **Creative Diversity** (CD), is based on the assumption that all human beings are creative, but in different ways[8]. This assumption conflicts with the popular view of creativity, which often sets apart certain people (e.g., artists) and/or certain kinds of ideas (e.g., "out of the box") as "truly" creative, while others are not. As noted in Figure 1, the four principles of Creative Diversity "bust these creativity myths" by defining four key variables to distinguish the creativity of one person from another: creative level (potential and manifest cognitive capacity), creative style (cognitive preference for structure), motive (how you channel your energy), and opportunity (what is available and how you perceive it)[8] – with every combination valued equally, although particular combinations may be more effective in specific situations. In the CIC MOOC, 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, Entrepreneurship, owNership, Tenacity, Excellence, and Relationship[8]. 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.

2.4 Course Structure and Content

Course Lessons: The course lessons were delivered over 6 weeks, with new material related to creativity, innovation, and/or change processes and techniques released each week; the weekly lesson topics are listed in Table 1. Students were expected to spend 3 to 5 hours per week on their coursework and were given 2 weeks to complete each assignment (a soft deadline after one week and a hard deadline after 2 weeks). Each lesson was structured around the following online components: videos, readings, exercises, reflections, and discussion forums. In addition, different types of social media (e.g., Facebook, Google+, and LinkedIn) were used to enhance student collaboration and communication outside the Coursera platform.

Table 1. CIC Weekly Lesson Topics and Exercises

Lesson/Week	Topic	Exercise
1	Introduction & Welcome	Shoe Tower
2	Creative Diversity	Creative Style Estimation
3	CENTER	Life Ring
4	Innovation	Bold Acts of Defiance
5	Value Creation	Action Map
6	Making Change Happen	Branding

Exercises and reflections: The MOOC students completed one exercise each week, in which they were given experiential tasks to perform that integrated the topics from that week (see Table 1). The main objective of these exercises was to encourage a creative mindset, promote innovative behavior, and help students become more proactive about driving change in their communities of influence. 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 of each exercise (e.g., posting a photo and written description of an artefact related to the exercise), students also answered open-ended questions involving reflections on their learning processes. In this study, we will focus on the first of the six exercises: the Shoe Tower exercise; further details of the exercise are provided in Section 3.

Discussion forums: The Coursera MOOC platform relies heavily on discussion forums for student-to-student and student-to-instructor interaction. The MOOC under investigation had a separate discussion forum for each major element of the course (videos, readings, exercises, etc.), as well as a general discussion forum and a "professor's journal" (for instructor reflections). For logistical support, there were separate forums in which students could self-organize study groups, as well as forums to address technical issues, errors in course materials, and suggestions/complaints about the course.

2.5 Grading and Assessment

Many of the activities presented in this MOOC were directed at students' personal growth, while others focused on the mastery of core principles. As a result, a strong emphasis was placed on students' personal learning paths and on building meaningful insights through the exercises and projects rather than accumulating "right or wrong" answers. A task list was defined for those students interested in earning a course Statement of Accomplishment that included the completion of 5 of the 6 weekly assignments. To complete a Statement of Accomplishment with Distinction, students had to fulfill all these requirements and also complete at least 2 peer reviews of other students' work for each submitted assignment.

2.6 Weekly Assignments

The six creative exercises (one per week) are described below. Students may complete the exercises on their own (no collaborative or cooperative work is required), although students are encouraged to form study groups and to share their submissions broadly, either through the CIC MOOC discussion forums or using other social media.

- **Week 1: Shoe Tower –** This exercise focuses on prototyping and appreciating the value of Intelligent Fast Failure. Learners build the tallest free-standing tower possible using only shoes. Students calculate the "T-value" of each tower, which is defined as the quotient of the tower height and the number of shoes. Learners also assess their own towers in terms of how creative and how beautiful they consider them to be, and reflect on the role of failure in completing the task to their satisfaction.
- **Week 2: Creative Style Estimation–** This exercise focuses on personal insight about preferred approach to creativity (known as "creative style"). Learners answer a set of questions related to the structure of their thinking. These questions are scored in Qualtrics, and an estimated creative style score is returned to each student. Students reflect on their results and the advantages and disadvantages of being the style they are.
- **Week 3: Life Ring–** This exercise focuses on setting goals and "centering" one's thinking in order to accomplish those goals. Learners construct a Life Ring that incorporates key driving forces, categories, desired outcomes, and important goals in their lives. Students reflect on their results and the action steps they took to move toward their stated goals.
- **Week 4: Bold Acts of Defiance–** This exercise focuses on challenging the status quo and learning how to tolerate greater levels of risk. Learners are instructed to defy a cultural norm without breaking the law or causing danger to themselves or others. Students reflect on the process they experienced and how what they learned might help them in future problem solving situations.

- **Week 5: Action Map–** This exercise focuses on identifying real needs by observing others in challenging situations. Learners identify multiple needs, pains, or problems in their communities and share those ideas with others to identify which problems they might pursue further. Students reflect on how they might prototype and test solutions to the key problem they identified.
- **Week 6: Branding–** This exercise focuses on establishing a personal "brand" to represent one's identity and/or the core of one's product or service offering. Learners construct tangible, authentic, and relevant items that present some aspect of what they as individuals and/or their products and services do or stand for. Students reflect on the meaning of their brand and how the course lessons affected their branding process.

In each of these exercises, many learners shared the results of their work (e.g., pictures of their Shoe Towers, images of their Life Rings, reflections on their experiences or insights) in online platforms where the works were accessible to the public, including the Coursera Forum. Others communicated through emails and some social media tools that only allowed group members to participate and view group discussions (e.g., QQ in China).

3. The Shoe Tower: Teaching IFF Principles through a Simple Hands-On Exercise

The task designed to encourage Intelligent Fast Failure (IFF) has evolved over the life of the CIC MOOC, which was first offered in 2013[8]. In that first offering, learners were asked to construct the tallest tower they could using a single sheet (8.5in×11in) of *paper*; no other instructions were provided. Following construction, learners were asked to reflect on their processes for building the tower and to report on what they learned by engaging in an exercise that required multiple attempts (or "failures") to reach an optimum solution. Coming at the beginning of the course, the twin aims of this simple exercise were (1) to put students in an active "creative mode" of learning, and (2) to illustrate the Intelligent Fast Failure process in daily life. The exercise was very popular with the MOOC students, with thousands of Paper Towers submitted. Still, we felt that the activity could be made even more accessible and enjoyable for MOOC learners, particularly those at the extreme ends of the age spectrum (K-6; senior citizens), when the fine motor skills required to manipulate paper might be limited. In addition, we felt that a different set of materials might encourage more "risk taking" behavior in building the tower.

As a result, in subsequent offerings of the course (2014-present), the tower-building materials were changed. Given the potential resource challenges of many MOOC students (e.g., those in developing nations), careful consideration was given to the materials required for the task, along with the reporting and reflection requirements for the assignment. The key challenge was availability: all materials had to be available to everyone who took the course, preferably at no cost. We considered Popsicle sticks, tooth picks, marshmallows, and other items that might be considered common in North America, but these materials had obvious drawbacks for learners in other cultures and countries. Eventually, we settled on *shoes* as an item that will be found in some form in every country/culture. We added several new design goals as well (described in Figure 2), while maintaining the fundamental aims of the exercise: students would be asked (1) to construct the tallest free-standing tower possible using only the stated materials, and (2) to report on their problem solving processes and outcomes, including their approaches to and experiences with failure and the application of IFF principles.

3.1 Instructions for the Shoe Tower Exercise

The new Shoe Tower exercise was comprised of two parts: basic instructions and reflection questions. The instructions were presented in both a written form (see Figure 2) and as a short (1-minute) video, featuring one instructor and several course assistants.

Basic Instructions: Build the tallest free-standing tower you can make entirely of shoes. Also think aesthetically: How beautiful is your shoe tower? How much art can you add to it (shapes, colors, etc.)? No other materials are allowed (i.e., no string, tape, glue, etc.). Take a picture, or draw a diagram, or write a description of your tower in words, and submit this together with the reflection questions to receive credit for the normal certificate or the certificate with distinction.

Measuring Your Tower: To make the problem more challenging, you must also measure your tower using the following formula. See how high a T-value you can achieve using the "T formula" shown below. (Note: The T value has <u>nothing</u> to do with a grade for this exercise.)

T-value = (Total tower height in cm) ÷ (Number of shoes).

Things to Notice: As you build your shoe tower, take note of the following things.
1. How many prototypes did you build before you were satisfied with your result?
2. How many times did your tower design fail? What did you learn from those failures?
3. How did building to the "T formula" impact your creativity? Did it inspire you, frustrate you, or both?

Figure 2. Instructions for the Shoe Tower exercise

3.2 Shoe Tower Reflection Questions

In addition to submitting an image and/or written description of their Shoe Towers, learners were also asked to complete the following four reflection questions regarding the experience:

1. Please provide an in-depth description of the process you went through in building the Shoe Tower, including number of attempts and revisions.
2. How tall was your Shoe Tower (in cm)? How many shoes did you use? What is the T-value for your Shoe Tower?
3. How beautiful was your Shoe Tower (rate it on a scale from 1 to 10, 10 being the most beautiful)? How did you assess this – by comparison, by survey, from friends?
4. For this exercise, where would you put yourself on a creativity scale from 1-10 (with 10 being highly creative)? One way to rate this question is by your own measure: how many attempts do you want to make, and how intense (e.g., in minutes) should each be? What value do you want to reach for yourself? Then: how well did you meet these goals?

The answers to these questions were submitted to a specific assignment portal in the Coursera platform and made available to other learners for peer assessment.

4. Research Methods

Given the MOOC and its aims, we proposed to study the students' performance in the Shoe Tower exercise, as well as their self-assessments and reflections, to help us understand the creative behavior of students in a global online learning environment. Specifically, we hoped to gain insight into students' application of IFF principles using the Shoe Tower exercise, with an overall view toward the effectiveness of this exercise for investigating IFF principles in an online environment. This led to the following research question:

- **Research Question**: Is the Shoe Tower exercise effective in teaching IFF principles in the MOOC environment?

To explore this research question, we analyzed relationships among the following variables based on students' reflection question responses:

1. Number of Shoe Tower attempts/revisions
2. Shoe Tower metrics: height, number of shoes, T-value
3. Shoe Tower "beauty rating"
4. Individual learner "creativity rating"
5. Demographic variables: gender, country of origin

The key *performance variables* included: (1) the number of Shoe Tower attempts/revisions (i.e., the number of attempts/revisions ***leading up to, but not including,*** the final solution), which represents the number of "failures" of the CIC MOOC students as they applied Intelligent Fast Failure principles; and (2) metrics associated with the Shoe Towers themselves (height, number of shoes, and T-value). The key *perception variables* included: (1) students' evaluations of the beauty of their respective towers ("beauty rating"); and (2) students' assessment of their own personal level of creativity based on their performance in the Shoe Tower task ("creativity rating").

If the Shoe Tower exercise is effective in teaching IFF principles in the MOOC environment, we might expect to see an improvement in both student performance and student perceptions as the result of increased attempts/revisions, which leads to the following hypotheses:

- H_1: Student *performance* in the Shoe Tower exercise will be positively correlated with the number of attempts/revisions;
- H_2: Student *perceptions* of the beauty of their Shoe Towers will be positively correlated with the number of attempts/revisions;
- H_3: Student *perceptions* of their personal creativity will be positively correlated with the number of attempts/revisions.

4.1 Demographic Data Collection & Study Participants

Demographic data were collected through a voluntary pre-course survey, which is administered by Coursera (the CIC MOOC platform provider) to all enrolled learners. Originally, 1955 students submitted responses to the Shoe Tower exercise. After filtering these unique submissions for students with valid demographic information, and eliminating submissions with missing items, 859 participants remained. As shown in Table 2, 56% of these 859 students were female, and 44% were male. In the CIC MOOC as a whole, 3,803 of the approximately 65,000 enrolled participants responded to the pre-course demographic survey; of these, 48% were female, and 52% were male[19].

Table 2. Demographic Comparison of Course Participants and Shoe Tower Participants

Comparison of Course Participants and Shoe Tower Participants	**In CIC MOOC**		**In Shoe Tower Exercise**	
	Number	Percent	Number	Percent
Gender	N = 3,803		N = 859	
Female	1,825	48%	480	56%
Male	1,978	52%	379	44%
Countries Represented	187		94	
Country of Participation	N = 3,803		N = 859	
China	913	24%	152	18%
India	266	7%	85	10%
United States	723	19%	137	16%
Other	1,901	50%	485	57%

As is also shown in Table 2, students participating in the Shoe Tower exercise represented 94 countries, which is approximately 50% of the 187 countries represented by the 3,803 students who registered for the course and completed the optional Coursera demographic survey[19]. This CIC MOOC attracted a significant number of Chinese learners (24% of those visiting the course at least once); this may be a result of the course contents being provided in Chinese as well as English, which reduced the language barrier. Chinese students also comprised a comparable percentage (18%) of the Shoe Tower exercise participants (the largest % for any country).

4.2 Shoe Tower Data Collection and Processing

The key data (number of Shoe Tower attempts/revisions, Shoe Tower metrics, "beauty rating", "creativity rating", and demographic variables) were downloaded from the Coursera database and saved in HTML format. Using the R programming language, the data were cleaned and numeric values were extracted: Tower Height, Number of Shoes, T-value, Attempts, Beauty Rating, and Creativity Rating. The extraction procedures for Tower Height, Number of Shoes, Beauty Rating, and Creativity Rating were straightforward; these values were recorded directly from the MOOC students' responses. Occasionally, students used different units than those requested (e.g., inches rather than cm; pairs of shoes rather than number of individual shoes), and these values were transformed to the appropriate units. The T-value score was re-calculated for each participant according to the T-value formula to check accuracy.

Extracting the number of Attempts was more challenging, as these values were reported in different ways within the students' reflection question responses: sometimes they were reported directly (e.g., "Attempts = 5"), and other times they were reported as part of the student's narrative (e.g., "I tried 6 different ways of building my tower before I hit on the final answer"). Note that students with blank answers had already been deleted from the data set; in addition, students whose answers were indeterminate (e.g., they answered "several times" or "many times") were also eliminated from the analysis to reach the full dataset of 859. We established data processing rules for extracting Attempts (i.e., the number of attempts before the final solution) from the student responses as follows:

1. If students identified their total attempts as "3-4 times", "5-7 tries", we recorded Attempts as (Reported Maximum – 1);
2. If students identified their total attempts as "I tried X times before the final one," we recorded Attempts as X.
3. If students reported their results in the form, "The number of attempts was X with Y revisions" or "I made X towers with about Y revisions for each", we calculated the appropriate Total and recorded Attempts as (Total – 1);
4. If the student described their prototypes one by one, we summed the mentions and recorded Attempts as (Sum – 1).

4.3 Data Analysis

Data analysis included both qualitative and quantitative methods; the quantitative analysis will be the focus here. Standard statistical software (R, SPSS) was used to calculate the descriptive statistics, correlation coefficients, ANOVA, etc. For some statistical analyses, variable transformation was necessary for normality, which is the assumption for hypothesis tests. Several transformation methods were applied; the best results came using Templeton's 2-step approach[15], which ensured that the highly skewed variables (e.g., Attempts, Shoe Tower Height, Number of Shoes, and T-value) were transformed to approximate normal distributions.

5. Research Findings

5.1 Types of Shoe Towers

Examples of some Shoe Tower submissions are presented in Figure 3. Our qualitative analysis of all submissions resulted in the identification of eight (8) different categories or types of Shoe Towers based on their structural features, namely: Brick Wall, Pyramid, Floor, Gladiolus, Pyramid + Gladiolus, Bridge, Pile, and Miscellaneous. A detailed analysis of these Shoe Tower types and their relationship to demographic variables (gender, country of origin, occupation) and variables derived from other CIC MOOC exercises (e.g., Creative Style Estimation) will be the subject of a future publication.

5.2 Analysis of Shoe Tower Attempts (i.e., "Failures")

We used the number of attempts students made leading up to the construction of their final Shoe Towers to represent the degree to which they applied Intelligent Fast Failure principles. In general, we believe students may apply IFF principles differently due to the presence (or lack) of different physical resources, different levels of satisfaction, different personal goals, different styles of creativity, and/or different prototyping skills. Although some students made only one attempt before settling on a final Shoe Tower solution, most tried multiple times before producing their final prototype; the exercise did not set a target number of attempts.

A brief summary of statistics for the number of Attempts (i.e., Failure Times) is provided in Table 3 (and illustrated in Figures 4a/b) in two forms: using original data, and using normalized data based on Templeton's 2-step approach[15]. When substantial skew exists in a dataset (as it did in our data), it is common to transform the data to a symmetric distribution before constructing a confidence interval. If desired, the confidence interval can then be transformed back to the original scale using the inverse of the initial transformation. Because Templeton's transformation is 1-to-1, the results of any correlation analyses and other statistical tests will be nearly the same as those carried out using the original distribution. Templeton's method can also make it easier to visualize skewed data distributions, as it did in our case (Figure 4b). Note that the negative values in the Normalized Attempts histogram correspond to values of 0 or 1 (Attempts).

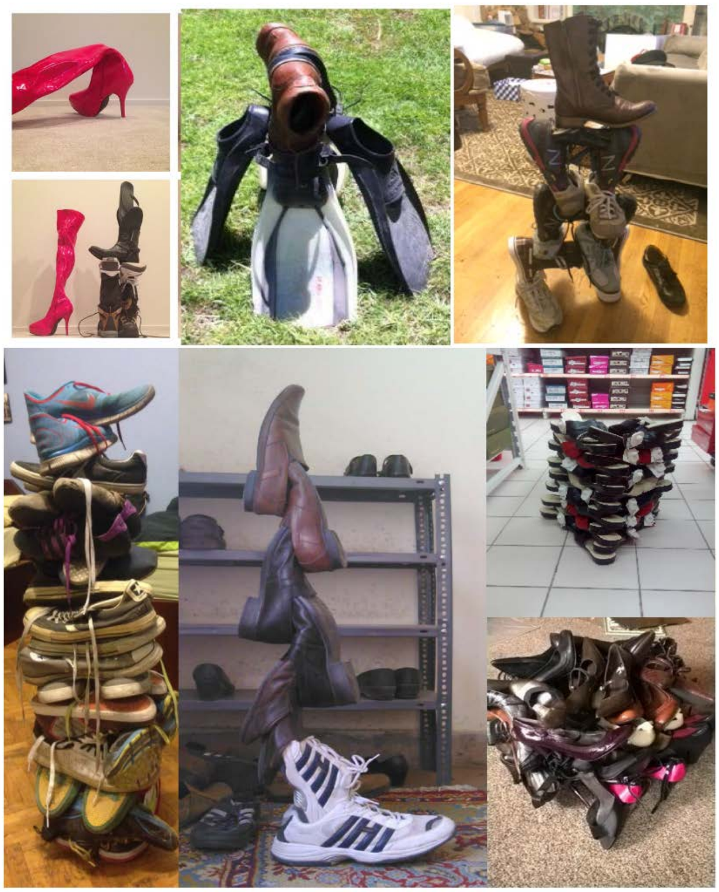

Figure 3. Examples of Shoe Tower submissions

Table 3. Summary statistics for Number of Attempts (Failure Times)

	Attempts (Failure Times)		Normalized Attempts (Normalized Failure Times)	
Statistics	Mean	4.86	Mean	4.90
	Median	3.00	Median	4.14
	Variance	32.84	Variance	30.21
	Std. Error of Mean	0.19	Std. Error of Mean	0.19
	Skewness	5.13	Skewness	0.063
	Kurtosis	44.01	Kurtosis	-0.247
	Minimum	0.00	Minimum	-8.55
	Maximum	79.00	Maximum	20.37

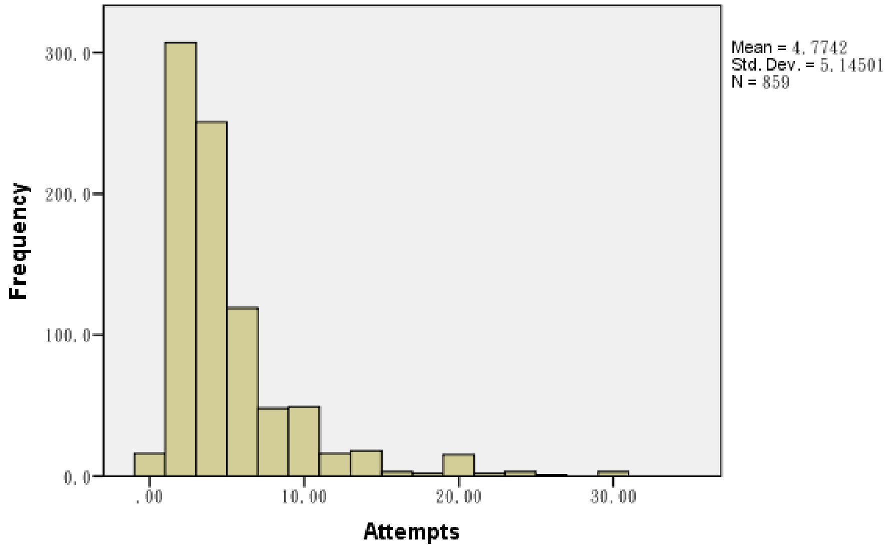

Figure 4a. Number of Attempts (Failure Times) across the sample: original data

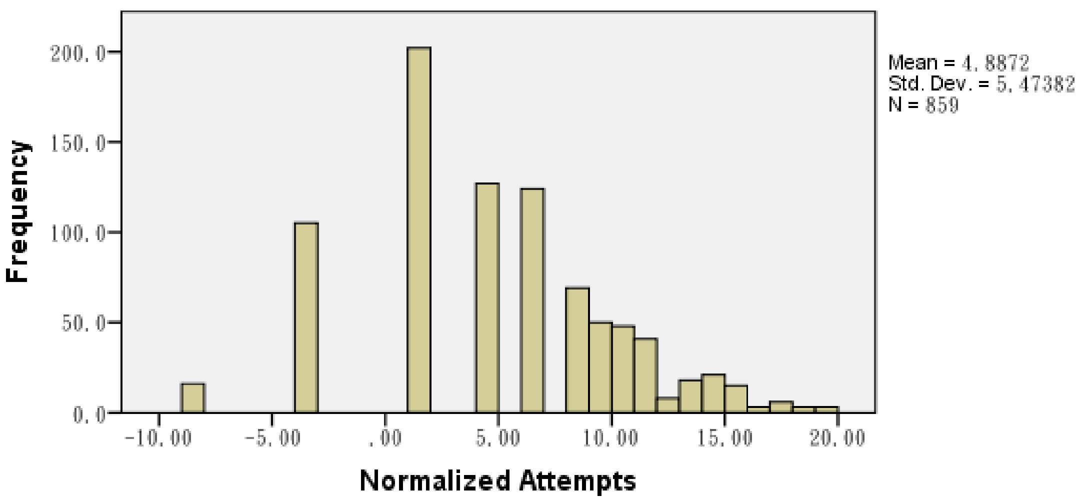

Figure 4b. Number of Attempts (Failure Times) across the sample: normalized data

5.3 Performance, Perceptions, and Number of Attempts – Overall Analysis

We computed correlations between the normalized Attempts (Failure Times) and the remaining performance and perception measures: normalized Tower Height, normalized Number of Shoes, normalized T-value, Beauty Rating, and Creativity Rating. As shown in Table 4, these correlation analyses show statistically significant relationships between Number of Attempts and 4 of the 5 performance and perception measures, namely: Tower Height, Number of Shoes, T-value, and Creativity Rating. The correlation between Number of Attempts and Beauty Rating was not statistically significant.

Table 4. Correlation analyses for normalized Number of Attempts

	Normalized Attempts (Failure Times)	
	Pearson Correlation	*p*-value
Normal Tower Height	0.080	0.019^{*}
Normal Number of Shoes	-0.077	0.024^{*}
Normal T-value	0.132	$0.001^{\dagger}$
Beauty Rating	0.014	0.689
Creativity Rating	0.070	0.041^{*}

$*p < 0.05$; $^{\dagger}p < 0.001$

Performance: These results indicate that higher Shoe Towers are positively associated with more Attempts, although the correlation coefficient is very low (0.08). Additionally, the negative correlation between Attempts and Number of Shoes (-0.077) implies that learners tended to use fewer shoes as they moved toward their final tower prototype, even though this magnitude is also very low. Finally, when we examine the correlation between Attempts and the T-value, the results imply that better overall performance is associated with more Attempts, with a slightly larger (but still low) correlation coefficient (0.132). In other words, the more attempts the students made (the more they "failed") before finalizing their Shoe Towers, the more "efficient" was their final result (greater height, fewer shoes). These results support our first hypothesis (H_1) that students will perform better through Intelligent Fast Failure (i.e., if the Shoe Tower exercise is effective for teaching IFF principles).

Perceptions: Although the magnitude is low (0.07), the positive correlation between Creativity Rating and Attempts is statistically significant, meaning that students perceived themselves as more creative with their increased Attempts at building a Shoe Tower. Repeated attempts did not lead to greater perceptions of Beauty in their outcomes, however. These results support our third hypothesis (H_3), but not our second hypothesis (H_2).

5.4 Differences between Genders

Performance: We also examined the number of Attempts for differences between our male and female students. Table 5 summarizes the descriptive statistics separated by gender, while Figure 5 shows Normalized Attempt distributions for males and females. The ANOVA results of Table 6 imply that the differences in Attempts/Failures between the males and females are not significantly different, regardless of variances or means. In other words, the male and female students tended to make a similar number of attempts before they reached their final Shoe Tower designs (i.e., roughly 4-5 times).

Table 5. Number of Attempts separated by gender

	Group Statistics			
	Gender	Mean	Std. Deviation	Std. Error Mean
Attempts	Male	4.43	4.08	0.23
	Female	4.60	3.97	0.20
	Total	4.53	4.02	0.15

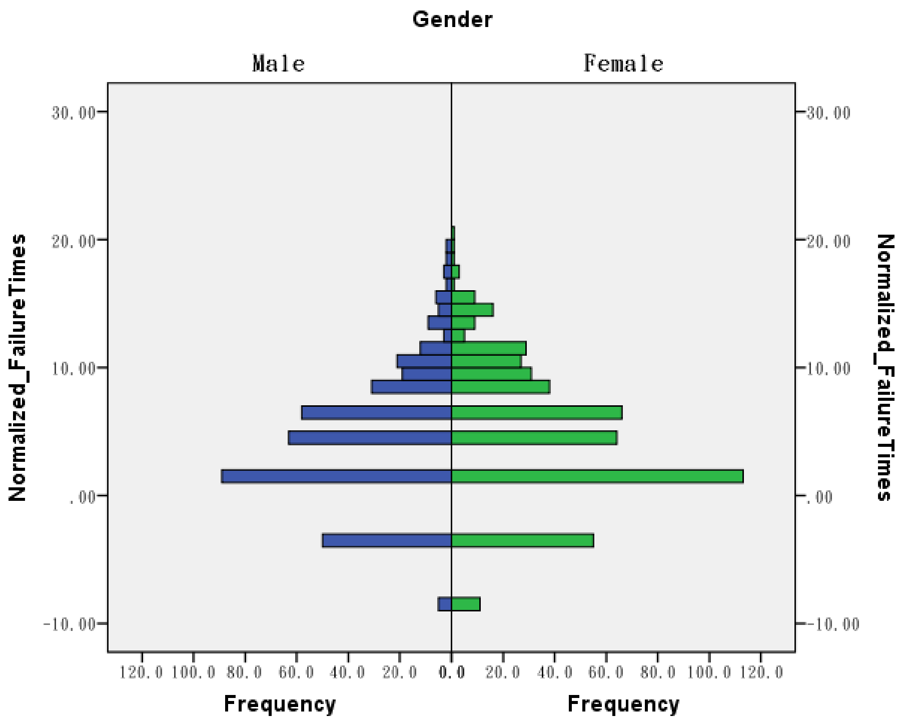

Figure 5. Normalized Attempts (Failure Times) separated by gender

Table 6. Levene's Test and t-Tests for Normalized Attempts separated by gender

	Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	*p*-value	F	*p*-value
Normalized Attempts	2.03	0.16	0.85	0.36

Perceptions: In terms of perceptions, there were no significant differences in the variances or means of the self-assessed Beauty Ratings or Creativity Ratings between genders.

5.5 Differences between Countries

Performance: Next, we investigated whether the Number of Attempts (Failure Times) differed by students' country of origin. In our sample of 859 learners, students from 94 countries participated; many of these countries only had a few participants, however. In order to have robust analysis, we focused on countries that had 19 submissions or more. After eliminating countries with fewer than 19 entries, 511 entries across 9 countries remained. Our analysis of these nine countries (see Tables 7-10) showed that the variances and means for Number of Attempts were different within this selection of countries, but further investigation was needed to determine which of these differences are statistically significant. As an example, the means and medians in Table 7 imply that the mean Number of Attempts was highest for the Chinese students (6.18), while the mean Number of Attempts of the Nigerian students was the lowest (3.05). The median Attempts of the Chinese learners (4.00) was also higher than that of the Nigerian learners (2.00).

Statisticians have developed various methods for comparing multiple group means, including the Tukey Test[16] and the Bonferroni procedure[3]. Based on the unequal group sizes and inequality of the variances for our data, these general post-hoc tests are not appropriate; instead, the Games-Howell test[5] was applied here. Using the Games-Howell test, we found the mean differences in Number of Attempts to be statistically significant between China and four other countries – Mexico, Nigeria, Spain, and the United Kingdom (see Table 10). Returning to our previous example, we can now confirm that the average difference in Number of Attempts between China and Nigeria (3.13) is statistically significant. Of course, while the results of Table 10 imply that Chinese learners made more attempts than the learners of the other four countries, they do not explain why; this could be the result of higher persistence or a different interpretation of the task requirements, but we cannot make any conclusions without further investigation.

Table 7. Summary statistics for Number of Attempts by country

		Attempts		
		Count	Mean	Median
Learners' Country	Australia	19	4.95	4.00
	Canada	19	4.47	4.00
	China	152	6.18	4.00
	India	85	4.99	3.00
	Mexico	21	3.24	3.00
	Nigeria	21	3.05	2.00
	Spain	29	3.41	2.00
	UK	28	3.86	4.00
	USA	137	5.10	3.00

Table 8. Test of homogeneity of variances

	Levene Statistic	df1	df2	*p*
Attempts	4.234	8	502	.000

Table 9. ANOVA for Attempts by country

		Sum of Square	df	Mean Square	F	*p*
Attempts	Between Groups	473.368	8	59.171	1.975	0.048
	Within Groups	15037.309	502	29.955		
	Total	15510.677	510			

Table 10. Post-hoc Games-Howell testing

Dependent Variable	(I) Country code	(J) County code	Mean Difference (I-J)	Std. Error	P value
Attempts	China	Mexico	2.946†	0.640	.000
		Nigeria	3.137*	0.748	.002
		Spain	2.770*	0.787	.018
		UK	2.327*	0.692	.027

*$p < 0.05$; †$p < 0.001$

Perceptions: We found no statistically significant differences in the mean Creativity Ratings across the 9 countries – i.e., students from the 9 countries rated their individual creativity in similar ways. However, the results of Tables 11-13 indicate that statistically significant differences in the students' Shoe Tower Beauty Ratings do exist among the 9 countries, with the mean Beauty Rating of China being higher than that of the United States by 0.88.

Table 11. Test for homogeneity of variances

	Levene Statistic	df1	df2	Sig.
Beauty Rating	2.992	8	502	.003
Creativity Rating	.541	8	502	.825

Table 12. ANOVA for Beauty and Creativity Ratings (9 countries)

		Sum of Squares	df	Mean Square	F	Sig.
Beautiful Rate	Between Groups	100.036	8	12.505	2.463	.013
	Within Groups	2548.947	502	5.078		
	Total	2648.984	510			
Creativity Rate	Between Groups	33.341	8	4.168	.740	.656
	Within Groups	2826.539	502	5.631		
	Total	2859.880	510			

Table 13. Post-hoc Games-Howell Test results

(I) Learners' Country	(J) Learners' Country	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
China	Australia	1.456	.583	.287	-.55	3.46
	Canada	.798	.618	.923	-1.33	2.93
	India	.111	.278	1.000	-.76	.98
	Mexico	-.394	.625	.999	-2.53	1.74
	Nigeria	.344	.453	.997	-1.18	1.87
	Spain	.362	.423	.994	-1.03	1.75
	UK	.428	.434	.985	-1.00	1.86
	USA	.878*	.271	.036	.03	1.73

*$p < 0.05$

6. Discussion and Conclusions

The results of our investigations suggest that the Shoe Tower exercise is an effective task for enhancing the creative performance and perceptions of students using the principles of Intelligent Fast Failure in a global, online learning environment. While the students' ratings of the aesthetic "beauty" of their creations were not influenced through the IFF process, their self-assessments of their creativity did increase, along with their performance. The Shoe Tower is a very simple task, and the magnitude of its impact (in terms of correlation coefficients) may have been "simple" (i.e., small) as well. Even so, the Shoe Tower exercise is clearly a useful and productive pilot model for teaching IFF principles and stimulating students' creative performance in the massive online learning community of the CIC MOOC.

What can engineering educators learn from these results? Whether the aim is teaching Intelligent Fast Failure or some other key principles, scaling up face-to-face classroom activities for use in an online environment – especially a *global* online environment – requires careful consideration to ensure that the new online activities are both accessible <u>and</u> meaningful across boundaries, including those associated with age, gender, culture, and social status. Our experience with the Shoe Tower (and other exercises) in the CIC MOOC points to a best practice that is easy to suggest, but challenging to do:

> ***Suggested Best Practice****:* To scale-up and transfer experiential classroom activities to the online environment, "boil down" the lesson, skill, or concept you want your online students to learn to its "essence" – and design a task (or set of tasks) that focuses on that essential piece and nothing else.
>
> In other words, <u>decide</u>: What is the ***one thing*** you want your students to learn if all else fails, and what is the ***simplest way*** to teach that ***one thing****?*

The assessment of experiential activities in an online learning environment requires equally careful consideration – and simplicity. What do you want to measure/assess, and what is the most basic way to do so, even if it yields data that is more "basic" than you would prefer? It is difficult enough to gather complete, reliable datasets in a face-to-face classroom environment; doing so in an online learning environment is even more difficult for a number of reasons, including validation of student identities, technical problems, language issues, and more. While our data collection and analyses for the Shoe Tower exercise relied on simple metrics (e.g., Tower Height, Number of Shoes, simple self-assessments, etc.), these metrics were accessible and meaningful across our global audience, leading to a response that was sufficiently strong (N=859) to be useful from a research perspective.

Our analyses also revealed several interesting facts about gender, country of origin, and simple prototyping behaviors that should be of interest to engineering educators. For example, the number of Attempts made by the male and female sub-groups in our sample did not differ in a statistically significant way – i.e., men and women "tried and failed" similarly when constructing their Shoe Towers. Their aesthetic (beauty) ratings of their Shoe Towers and their assessments of their own creativity were also statistically similar. These results suggest that, on average, men and women may be equally persistent in experimenting with failure and equally confident (or not) in their own creative skills. Similar analyses based on country of origin led to more complex results. It is more difficult to interpret the combination of statistically significant differences observed between the responses of students from China and those from several other nations (Mexico, Nigeria, Spain, UK, US), but the fact that they exist in the context of the Shoe Tower exercise highlights the need to consider how IFF may be viewed differently in different cultures.

7. Study Limitations and Future Work

Because the CIC MOOC students were only asked to submit photos, drawings, or descriptions of their *final* Shoe Tower solutions, we were unable to observe and analyze the evolution of their Shoe Tower prototypes, which might reveal even more about the impact of IFF principles and students' application of and response to them. We are currently updating the Shoe Tower exercise to include a request for students to submit a series of photos, drawings, or descriptions that records their prototyping progression, rather than just their final solution.

In addition, some researchers may argue that the Shoe Tower exercise is not difficult or complex enough to truly represent engineering problem solving. The principles of Intelligent Fast Failure will support more complex tasks and testing protocols than those involved in this simple exercise, and we hope to explore more complex exercises in future versions of the CIC MOOC or in other online venues. However, we believe that our experience with the Shoe Tower exercise has shown the value of using *simple* experiential tasks in online learning environments, and we encourage educators to consider the benefits of this approach, if only as a first step.

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