Leveling Up by Gamifying Freshman Engineering Clinic

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Joseph Gulotta is a member of Rowan University's Class of 2016, graduating with a BS in Electrical and Computer Engineering. His first job will be at DataStream Technologies Inc. as an Applications Engineer, working primarily on HVAC controls. The interest to work on this research and conference paper came out of a desire to help create course content that is a new and innovative take on engineering course design.

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My name is Nicholas Parisi, and I studied electrical and computer engineering at Rowan University. I am very interested in wearable devices, sensors, app development, and writing code to integrate software and hardware. In terms of ASEE, I had the unique experience of helping develop the platform that would be presented to freshmen engineers, in order to see how a complete drastic change in homework would affect student's motivation and desire to complete the work.

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Cheryl A. Bodnar, Ph.D., CTDP is an Assistant Professor in the Department of Chemical Engineering at Rowan University. Dr. Bodnar's research interests relate to the incorporation of active learning techniques in undergraduate classes as well as integration of innovation and entrepreneurship into the engineering curriculum. In particular, she is interested in the impact that these tools can have on student perception of the classroom environment, motivation and learning outcomes. She obtained her certification as a Training and Development Professional (CTDP) from the Canadian Society for Training and Development (CSTD) in 2010, providing her with a solid background in instructional design, facilitation and evaluation. She was selected to participate in the National Academy of Engineering (NAE) Frontiers of Engineering Education Symposium in 2013 and awarded the American Society for Engineering Education Educational Research Methods Faculty Apprentice Award in 2014.

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Abstract
This Work-In-Progress paper describes the development of a gamification platform for a multidisciplinary freshman design course at Rowan University. This course is designed to teach engineering students about multidisciplinary design, with special focus on developing skills associated with teamwork, software application and ethics. An important part of learning is receiving feedback as part of the learning cycle and studies have shown that increased feedback can be helpful in supporting student reflection and developing the intrinsic motivation necessary for mastering a task. One method of encouraging students to master material is by providing students with immediate feedback through gamification platforms. The gamification platform being employed in this implementation uses interactive learning techniques to provide students with clear cut goals as well as immediate feedback as an indicator of the student's performance.

Gamification transforms the traditional homework layout into an entirely new entity. Students can work to earn badges by completing assignments that interest them within the platform. Students also have the power to learn at their own pace and mechanics such as experience points, badges, leaderboards, and achievements can be used as motivating factors to encourage student completion of activities. In addition, the system acts as a scaffold for the students starting with activities that are easier and become progressively more challenging as their knowledge increases while allowing them to repeat tasks as necessary to encourage mastery of course material.

The effectiveness of this platform will be assessed by a combination of quantitative and qualitative measures. Student activity completion, accrual of badges and achievements, and the process through which students select the activities to pursue will all be monitored. Students will also complete the MUSIC model of academic motivation to measure their engagement with class activities as a result of the addition of the gamification platform. Qualitative feedback from students will be collected through focus groups to gain a better appreciation for how the gamification platform impacted their course experience.

Introduction
Freshman level courses play an important role in a student's decision to stay in or leave engineering, as it is shown that the largest exodus out of engineering occurs after the first year of college.[1] A report from the U.S. Dept. of Education in 2009 demonstrated that out of engineering majors enrolled in their program in 1995-1996 only approximately 60% of them stayed within engineering by the time they completed their degree program.[2] Similarly, a recent case study by Honken and Ralston showed that only 76% of freshman engineering students were retained within engineering.[3] Although the trend in increased retention is promising it is far from where educators would like it to be.

Factors that can influence a student's decision to persist or leave freshman engineering has been shown to be influenced by multiple factors. A study of 113 undergraduate engineering students at a large eastern university showed that both academic and non-academic factors can influence a student's decision to persist within engineering.[4] Academic reasons included curriculum difficulty, poor teaching and poor advising while non-academic factors included feeling that they did not belong within engineering. For this reason, publications that seek to provide counsel to

institutional administration and faculty on how to address these low retention rates have become more prominent in the literature.[5, 6] As suggested by Lau[6], one method that faculty may use to improve student retention is the incorporation of multimedia technology since it can be used to garner attention from the students while enriching their classroom experience. This study seeks to employ a gamification platform as a means of improving upon student retention and motivation for pursuit of engineering skillsets within a freshman multidisciplinary design course.

Gamification is defined as using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems.[7] Applying video game elements such as interactivity with a platform, graphics, and an incentive system promote prolonged use of a platform and will even cause the student to delve further into the topics within.[8] The students who are entering college today have grown up with computers and games, and to them this technology is just another part of life.[8] In Canada, roughly 80% of teenagers (ages 13-17) consider themselves gamers, and 67% of adults (ages 18-34) consider themselves gamers.[9] Out of the people who said they were gamers, 42% of teens, 49% of adult males, and 45% of adult females play video games at least a few days per week.[10] As games grow in popularity, educators are beginning to realize that educational games offer a new path of learning that may prove to improve upon the traditional learning system.[11]

Results from gamifying first year courses have proven to be successful.[12, 13, 14] One specific gamification implementation served as a library orientation for first year engineering students. This implementation taught the students how to properly find and cite credible academic sources and utilize the library to their full advantage. Results from this implementation showed that it lead to better teamwork, as well as having a positive impact on the student's ability to learn the course content. The results also showed a two-fold increase in the use of credible sources when the students were asked to study existing engineering design applications. In addition, the course's success was shown in certain students' approach to the coursework, choosing to work and strategize in teams (and therefore accomplishing more tasks quicker) as opposed to just trying to take on the challenge alone. The assessment of the gamification's effects on student learning in this example was done by reviewing student presentations using a simple point system. If a source that a student presented that was properly cited could be traced back to the gamification activities put into place, a point was awarded. This number was then compared to past data to determine whether or not the platform was an effective learning tool.[15]

The course that will undergo gamification in this application is a first year multidisciplinary engineering design course. This course enables students to think and design like practicing engineers, requiring them to consider factors like ethics, intellectual property rights, environmental consideration, manufacturing techniques, etc. in their design choices. The students will work in multidisciplinary teams to accomplish a final design project, allowing them to participate actively in a design effort that simulates real world applications. In addition to the final design project, students will also continue to develop their communication skills, time management, and critical thinking skills from the previous design course in the fall semester. In this paper, we present an overview of the gamification framework and activities being built into the class as an alternative to traditional homework assignments for this first year multidisciplinary engineering design course. The gamification framework is constructed using the successful gamification software platform 3D GameLab.[16] Herein are described the research

questions for this platform, the platform activity (or quest) design, the implementation plan, the assessment plan, and summary.

Research Questions

The freshman engineering course that was selected for implementation of the gamification platform covers a wide range of multidisciplinary topics that are prevalent within all engineering disciplines. The overarching topics include professionalism, engineering mathematics, communication, efficiency, ethics, and project-based tasks. Gamification of the homework within this course serves multiple goals. The progression through the gamification platform should allow the students to feel freedom of choice and control over their learning providing for a personalized learning environment where students can learn at their own pace. In addition, the gamification platform should motivate students to complete their course work through leveraging principles related to both intrinsic and extrinsic motivation such as personal goals, satisfaction at mastering a category of quests, their position on the leaderboard, and attainment of badges and achievements. This study seeks to investigate the following research questions:

1. What course topics do students devote the most time to within the gamification platform and does this correlate to the types of quests provided to students within this content area?
2. What elements of the gamification platform influence student progression through the quests and how are these tied back to intrinsic and extrinsic motivation theories?
3. Are there any observed changes in student course performance as a result of incorporation of the gamification platform?

Gamification Activity Design

The gamification platform was designed to have nine different levels that act as a scaffold for the students' progression in the course with quests at each level becoming increasingly more challenging than the previous level. Each level requires students to accrue 250 experience points (XP) to achieve the next level, which then opens up new quests assuming all prerequisite quests have been successfully completed. Table 1 shows the level name and its corresponding experience points range and grade based on 1250 XP corresponding to an A for homework in the course.

Table 1. List of Levels and Corresponding Experience Points and Grade

Level	XP Range	Grade
Peon	0 – 249	F
Grunt	250 – 499	F
Coffee Runner	500 – 749	D
Intern	750 – 999	C
Engineering Apprentice	1000 – 1249	B
Engineering Assistant	1250 – 1499	A
Engineer	1500 – 1749	A
Professional Engineer	1750 – 2499	A
CEO	2500 – MAX	A

Compared to the standard classroom usage of homework, the quests were designed to transform homework into an entirely new experience. The goal when creating quests was to make quests as unique and engaging as possible. To achieve this, quests tasked students with a variety of different types of activities including interviewing professors, surveying fellow students on campus, and creating presentations about a hobby. Making these quests unique and appealing to students' interests was also used as a means to increase student motivation for completing the quests. The quests were designed to fall under six over-arching topics based on the course objectives: professionalism, communication, efficiency, mathematics, ethics and teamwork.

Different learning styles that were targeted included visual, personally reflective, and hands-on (kinesthetic). For example, mathematics quests that involved mastering statistics and making predictions based off trends had students voyage out to campus and survey students and professors to collect data and then proceed with calculating the desired statistics. Topics students had been previously exposed to like dimensional analysis and significant figures involved quests that were designed to focus on audio and visual learners using songs and videos. Project based quests were designed to teach teamwork skills by having students engage with their final project team to complete online team building games or build teamwork skillsets from playing video games, sports on campus, or going to work-out at the campus gym. The students are asked to reflect on what teamwork skills were gained and how they were applied to completing the task. Submissions are in the form of a quick reflective presentation.

Besides using experience points and leaderboards as motivation, mechanics such as achievements, badges, and rewards are used to encourage students to complete quests. According to Mozilla's Open Badges, a badge is considered to be an online representation of a skill you have earned.[17] Achievements and badges are built into the game to automatically reward experience points based on the completion of a specific number or type of quests. There is a specific difference between badges or achievements and rewards; students know how badges and achievements are unlocked but rewards are completely unknown to the players. Rewards are given out at the professor's discretion. If a student is excelling through certain quests, the professor can go into the game platform and award additional experience points based on that performance. Students can work to earn specific badges by completing quests that interest them or are tailored to their learning style. The desire to acquire specific badges allows the students to feel as though they have more control over their learning because they have the power to determine how they earn experience points and maneuver through the gamification platform. Tables 2 and 3 shows a list of the badges and all of the achievements and what requirements the students need to fulfill to have them rewarded.

Table 2. List of Badges

Badge	XP Awarded	Availability
Quest Sampler	50	Complete at least one quest from each topic
An Introduction	50	Complete all Peon level quests
Trifecta	50	Complete three quests from each topic
Straight-Edge	50	Complete all ethics quests
Fortune Teller	50	Complete all stats quests
Mr. Wall Street	50	Complete all economics quests

Badge	XP Awarded	Availability
Quest Sampler	50	Complete at least one quest from each topic
Someone Call the Doctor	50	Complete all Heart-Lung quests
Mathemagical	100	Complete all Math Based quests
Smooth Talker Passed Grammar School	150	Complete all Communication and Grammar/Writing Quests

Table 3. List of Achievements

Achievement	XP Awarded	Availability
Welcome to the Big Leagues	10	Complete one quest
You Remembered	10	Complete Sig Fig and Dimensional Analysis quests
Big 10	10	Complete 10 quests
Terrific 20	10	Complete 20 quests
Experience Rush	20	Reach Coffee Runner in 30 days
With Extra Cream and Sugar	20	Reach Intern level in 45 days
Making Gains	10	Complete 30 quests
Fantastic 40	10	Complete 40 quests
Fifty Fifty	10	Complete 50 quests

Implementation Plan

To determine the impact the gamification platform has on students' motivation to complete course homework, it will be implemented in two second semester, multidisciplinary design freshman courses. One of the important decisions in implementing the game platform was supplementing the existing curriculum as opposed to replacing it.

The platform has deadlines for minimum monthly and course XP goals. Students are expected to have at least 1250 XP when the course ends as this component of their grade is only 15% of their total course grade. This is a reasonable benchmark because if all quests are completed and badges and achievements are unlocked there is a total of 3475 XP possible. A typical semester lasts for about three months. With that being known and the ultimate goal being set to 1250 XP, a benchmark for at least 350 XP per month is expected. The argument can be made that setting benchmarks prevents students from freely choosing the game platform; they only attempt the quests to fulfill the requirement. A previous gamification implementation by Author 3 showed that deadlines were necessary.[18] In the previous implementation of a game platform without deadlines students completed minimum quests because there were not any expectations. If the platform was completely optional the majority of the students would not acknowledge the platform or would not make a completely serious attempt at the quests as seen in the previous iteration. The benchmarks are there not to infringe on the students' freedom but to assist by setting a realistic, monthly and final XP goal to exceed.

Assessment Plan

The assessment of the gamification platform will investigate three specific research questions as outlined in the objectives section of the paper. The first research question to be addressed is

what course topics do students devote the most time to within the gamification platform? This will be evaluated by observing how many students completed quests within each specific quest category and the average amount of time students rated was necessary for quest completion.

The second research question for this study examines what elements of the gamification platform influence student progression through the quests, and how these relate to intrinsic and extrinsic motivation theories.   Specifically, student motivation will be determined by utilizing the MUSIC Inventory.[19, 20] This model of motivation tracks five key areas of student motivation: the feeling of choice or empowerment, the usefulness of material learned, students' belief in their own success, their interest in the content, and whether the students believe that the professor cares about them as a student. Focus groups with students in the classes will be used to provide additional qualitative data on student perceptions of their intrinsic and extrinsic motivation to partake in the gamification platform.

The final research question to be investigated includes determining if there are any observed changes in student course performance as a result of the incorporation of the gamification platform. This will be assessed by comparing the exam grades received by students using the gamification platform with those of students in a comparison class. The measure of success of the implementation will be measured using t-tests and their non-parametric equivalent, to determine if any differences exist between the intervention and comparison classes. Students will be randomly assigned to both the intervention and comparison classes and student GPA will be used as a control variable for the analysis performed to ensure meaningful comparisons are taking place.

Summary
Improving student engagement in engineering is an important component of any freshman curriculum. As shown in previous studies, gamification when applied within an engineering design course can create a stimulating, playful, and an exploratory learning environment that can motivate students to not only persist in the content area but go above and beyond the course requirements.[15, 18] In this study, we outline the creation of a gamification platform to increase student engagement within a multidisciplinary freshman course. The designed gamification platform incorporates activities that are designed to reach several different learning styles and engages students with their fellow classmates, students on campus, and professors to complete tasks in ways that may not be possible in a typical classroom environment.

The gamification platform will be assessed in Spring 2016 for its ability to motivate the students to engage with course material more than they otherwise would have and appeal to them through use of a unique teaching style. This study investigates what course topics students allocate the most time to within the platform and whether it correlates to the available quests? The study also aims to answer what specific elements of the gamification platforms influence students' progression and success. Ultimately, the study hopes to find if the gamification platform appealed to students and how the combination of the unique tasks and motivational elements such as badges and leaderboards motivated students to succeed.

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