Gamification of Engineering Courses

Dr. Zakaria Mahmud, Lake Superior State University

Dr. Zakaria Mahmud is an associate professor of mechanical engineering at Lake Superior State University (LSSU), Sault Ste. Marie, Michigan. Prior to joining at LSSU, Dr. Mahmud taught at North Dakota State University, Georgia Southern University, and Texas A&M University. He received his bachelors from Bangladesh University of Engineering and Technology (Bangladesh), masters from the Royal Institute of Technology (Sweden), and doctoral from the University of Alabama (Alabama). His background is in the general areas of thermal fluids with specialization in aerodynamic flow control.

Dr. Paul J. Weber, Lake Superior State University

Dr. Paul J. Weber is an Associate Professor in the School of Engineering & Technology at Lake Superior State University. His primary interests are in the areas of engineering education, renewable energy conversion systems, sustainability and resource usage, robotics, and digital systems.

Dr. Joseph P. Moening, Lake Superior State University

Dr. Joseph P. Moening is an Associate Professor in the School of Engineering & Technology at Lake Superior State University. His primary interests are in the areas of engineering education, renewable energy conversion systems, and power electronics.

Gamification of Engineering Courses

Zakaria Mahmud, Paul J. Weber, and Joseph P. Moening
School of Engineering & Technology
Lake Superior State University
Sault Ste. Marie, Michigan, 49783, USA
Email: zmahmud@lssu.edu, pweber@lssu.edu, jmoening@lssu.edu

Abstract

Integrating game-like elements into the classroom is becoming more common given the increasing popularity of video games. Early research shows that educational gamification—implementing game-like elements into an activity—can increase students' motivation and engagement. The key objectives of this research are: a) investigating student perceptions about gamification within the demography of the authors' institution, and b) understanding if/how the students' overall learning of the course materials improve via gamification. Five engineering courses, all of which are either in the core or are elective classes of the electrical and computer engineering curricula or , were tested with game-like elements over the span of two semesters. The gamified contents were implemented in Moodle using recently available plugins that enabled activities such as badges, experience points tracking with levels, leaderboards, and quizzes with automated feedback. The results were derived from gathering students' views about gamification and course activities from an online survey that each student in the course had the option of completing.

A brief summary of the results show that students identified a lack of time and poor time-management as key barriers to their learning. Furthermore, students viewed that immediate feedback, and having repeated attempts of similar but different questions (akin to gamified learning through trial and error) were very helpful in their learning. However, students also indicated that the game-like elements, on average, were minimally helpful towards their motivation. This is likely due, in part, to the limited amount of gamification that was incorporated into the courses at this time. The results also show that the combination of gaining experience points and "leveling up" (nor the two individually) is not a strong motivator. Instead, students recommended that activities be tied to extra credit such that they influence the course grade. Survey results also indicated that the groups' of students often played games to win. As such, creating more meaningful goals/challenges for the students to complete may also help with motivation.

1. Introduction

The popularity of games, especially video games, seems to be ever-increasing. Incorporating game-like elements into activities can potentially make them more appealing to people as well as increasing levels of engagement. That is the theory behind gamification.

"Gamification" is a term that is difficult to define [1], but generally refers to adding game-like elements into an activity that is not traditionally considered a game. While gamification is not limited to the classroom, a number of recent research projects have explored gamification as it

relates to education. Some examples include examining the gamification of engineering courses [2], in which students could earn experience points (XP) for completing various activities and were awarded badges for completing enough activities. In addition, a leaderboard was used to add a competitive and social aspect. Students reported that they were more motivated and more interested, but also that it required more work.

Gamification is a relatively new area of research but, based on the current overview of research [3], it has been shown to result in increases in student motivation and engagement. However, they indicated that more research is needed to determine whether this is a long-term benefit or if there is only a short-term benefit due to the novelty of the gamification.

In this work, game-like elements were added into various electrical and computer engineering (ECE) courses. In total, there were three freshman/sophomore-level (Fr/So) courses—covering digital logic, programming with Matlab, and circuit analysis—as well as two junior/senior-level (Jr/Sr) courses covering digital design and machine vision. To understand if/how gamification helps with motivation, students completed surveys in which they rated the perceived effects of each gaming element. Their survey also included questions about common learning barriers, inquiries about what gamification is and students' tendencies when they play games, and how helpful certain course activities were.

Due to the small student populations in the individual classes, direct measures of student performance would not be statistically significant. As a result, the primary measure of success is qualitative by surveying students. The survey questions were geared towards understanding if/how gamification helps in motivating the students to learn better.

The remainder of the paper is organized as follows: The *Background* section explains general gaming elements and how they can be implemented, using the authors' approach in Moodle as an example. Next, the *Methodology* section describes the specific elements used in this work and then describes the survey that students completed to gauge the effect gamification had on their motivation and learning. The *Results* section describes key findings from this survey and their implications towards course organization. Finally, the *Summary and Future Research* provides a synopsis of the paper and its contributions describing potential avenues for future research.

2. Background

Gaming elements can be primarily divided into two different classifications: *self-elements* and *social-elements* [4]. Self-elements encourage students to compete against themselves and include things like experience points (XP), levels, badges, etc. Social-elements on the other hand motivate students to compete or cooperate against each other and include items such as leaderboards, discussion boards, etc.

Experience points (XP) are usually awarded whenever the user completes an activity. Levels usually incorporate XP and are assigned based on the total number of XP the user has acquired. Obtaining varying amounts of XP will allow the user to "level up" similar to achieving a higher rank. Both XP and levels are intended to encourage the user to complete as many activities as possible in order to obtain the most XP and highest level possible. Badges are usually awarded after completing a specific series of activities. The activities are generally selected such that the

user must prove their knowledge/skill in a particular area. Thus the badge is intended to show the user that he/she has mastered a particular topic.

A leaderboard is designed to show the user how he/she compares to all of the other users. Leaderboards can be based on the user's XP or other measures such as course grade. They can be anonymous or display the user's true name. Leaderboards are designed to encourage competition amongst the users by displaying their status. Discussion boards provide a means for users to help each other by asking and answering questions.

Given the ever-increasing demands on a faculty members' time, it is important to make the implementation of gamification as automated as possible. As such, using a learning management system such as Moodle is desirable. Ideally, educational activities should be designed to be achievable, allow students to have multiple attempts, increase the difficulty as the student progresses, and provide multiple methods for a student to complete a given learning activity [5], [6]. If various plugins are installed, Moodle can provide many ways to facilitate gamification in a course including: avatars, progress bars, quiz results, points/levels, feedback, badges, and leaderboards [6].

3. Methodology

At the authors' institution, gamification was first introduced in two engineering courses in spring 2016. The courses were EGNR140: Programming with Matlab and EGEE125: Digital Fundamentals. In fall 2016, EGNR140 was again taught in a similar manner and gamification was incorporated into the several other engineering courses, namely EGEE210: Circuit Analysis, EGEE320: Digital Design, and EGRS430: [Systems Integration &] Machine Vision. The Fr/So courses are all within the core of the electrical and computer engineering programs. The Jr/Sr courses meanwhile are electives (except for EGEE320 which is required for computer engineering students). However, all courses included at least some students from other engineering and engineering technology disciplines. The list of disciplines includes electrical engineering (EE), computer engineering (CE), mechanical engineering (ME), manufacturing engineering technology (MfgET) and electrical engineering technology (EET). One student from chemistry major also took EGNR140.

The learning management system—Moodle—was used to simplify the gamification process in all courses. This study focused on the following gamification elements: experience points (XP), badges, levels, leaderboards, and quizzes that could be taken multiple times (often viewing feedback between attempts based on their answers, and often with the new questions being similar yet different from the original attempt). Initially, in spring 2016 only badges were used as the reward system, later with the advent of new Moodle plugin 'Level-up!', all of the elements mentioned above were able to be incorporated.

Experience points were awarded based on students' activity completion. The activities chosen were the completion of quizzes, review of lecture slides and pre-lecture videos, completion of pre-lecture questionnaires, and clicking on web links. The total XP gathered from all activities put students into pre-determined levels. The levels were different for each course depending on the class activities and number of XP possible. Students could see their progress towards the next level and see their position within the class anonymously, using the Level-up! plugin.

An online survey questionnaire was used to collect student feedback and determine whether the gamified courses actually increased student motivation and engagement or not. The questionnaire was categorized into five sections:

- Barriers to student learning, based in-part on [7],
- Students' comprehension of what gamification is,
- Which player types students most identify with from the Bartle taxonomy: achievers, explorers, socializers, or killers,
- Students' views on how the gamified aspects did or did not impact them, and
- Students' opinions on the level of helpfulness of specific gamified course elements/activities (some of which were hypothetically asked if that particular element/activity was not implemented in a given course).

At the end of the semester, the survey questionnaire was given in Moodle with a fixed due date. Students earned extra credit for doing so regardless of whether they allowed their results to be shared in the research publications. It is important to note that 6 students that took the survey as part of EGEE320 also completed it for EGRS430. Such students were instructed to use the same answers for both, so the duplicate answers were removed from the EGRS430 response set.

4. Results

The results of the survey are next described using the previously mentioned sections:

4.1. Barriers

Students were first asked which of the following issues was often a barrier to learning, marking as many as were applicable (i.e. they could choose multiple barriers):

- Lack of time (to study, complete projects, etc.)
- Inability to use effective time management
- Class concepts are too complex
- Lack of confidence
- Not able to stay focused when studying/working
- Not motivated to put time and effort into course
- Not interested in course material
- Do not have access to information and/or appropriate technology
- Have a disability
- Lack of timely feedback on submitted work
- Negative social interactions with peers/classmates
- Negative social interactions with instructors
- Lack of clarity in instruction

The results of this portion of the survey can be viewed in Figure 1, where 7 of the most often chosen barriers are shown explicitly while the average of the least chosen 6 is shown last. The results are broken down between the Fr/So-level classes (EGNR140 and EGEE210) compared to Jr/Sr-level classes (EGEE320 and EGRS430). Similar comparisons were not done for other

survey questions because gamification was not implemented uniformly throughout the classes and the results would have been impacted by more variables as compared to the general questions.

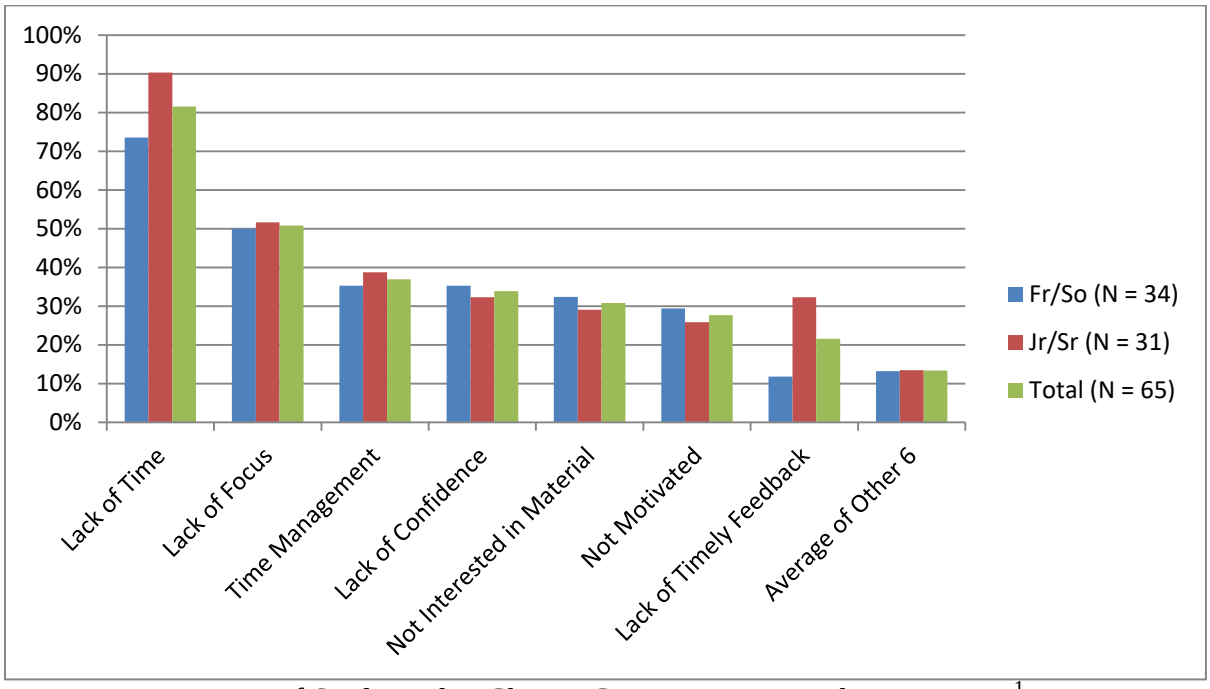

Figure 1: Percentage of Students that Chosen Given Barriers to Their Learning[1]

As depicted in Figure 1, the top three barriers were lack of time (marked by 81.5% of the students), inability to stay focused (marked by 50.8%), and inability to use effective time management (marked by 36.9%). All of these barriers are related to time and students' effectiveness in using it (on either a micro or macro scale). It is interesting to note that the students from the Jr/Sr classes cited time as an issue more often (90%) than those from the Fr/So classes (74%). One of the key goals of this study was to see if gamification favors students in their learning. Since time management is one of the top barriers, gamified course content with flexibility in time and often the possibility of multiple attempts is expected to minimize this barrier to the students' learning.

Students could also list other barriers in an open-ended question. The only common theme in the responses was activities (e.g. sports) that limited time. Other isolated example responses included being sick and not fitting in with the traditional educational system. For context, the authors' university contains many first generation students and is not a highly selective university, which could impact common barriers that were chosen. In terms of gamification, improving motivation with this specific set of students might not have as large of an impact on learning as compared to activities that improve the efficiency of learning and/or encourage students to use their time more effectively.

[1] Within the set of least chosen 6 barriers, "Lack of clarity in instruction" was chosen by ~23% of the students while all other barriers were chosen between 8% and 15% of the time. Besides Jr/Sr citing lack of timely feedback on assignments as more of an issue (32% vs 12% for the Fr/So), the two sets of populations were fairly consistently similar with differences (within ~7% points at most, with many within 1-3% of each other).

4.2. Students' Comprehension

The purpose of the next sets of questions on the survey was to gauge if students generally understood the concept of gamification for validity reasons. The first set of results is shown in Table 1, where students were asked which items were goals of gamification (they were again allowed to select multiple answers).

Table 1: Student selection of gamification goals

Increase Motivation	**Increase Learning**	**Integrate Online**	**Increase Enjoyment**	**Increase Competitiveness**	**Increase Game Skills**	**None of the Above**
82%	54%	34%	69%	55%	5%	2%

Over 80% of the students correctly identified that increasing the motivation to learn is a goal of gamification. Over 50% also chose that the ultimate goal is to increase learning via [increased motivation,] increased enjoyment, and mechanisms such as those that increase competitiveness between peers. Very few selected increasing gaming skills, which is *not* generally a goal of gamification. Integrating online technologies was *not* a goal of the gamification work in the class. While the technology did help enable some aspects, the same gamification goals could have been achieved in different ways that did not utilize online technology. Students were also asked to identify specific attributes of gamification, the results from which are shown in Table 2. From these, it was observed that students most often recognized gamification aspects that were more emphasized by the instructors and/or implemented within the classes.

Table 2: Student selection of gamification elements

Achievements	**Exploration**	**Trial & Error**	**Competition**	**Socialization**	**Time Constraints**	**None of the Above**
75.4%	44.6%	50.8%	55.4%	36.9%	23.1%	3.1%

4.3. Player Types

After collecting data about students' knowledge of gamification, the next set of questions attempted to gauge to what degree the students identified with each of the player types from Bartle's taxonomy. The results of these questions are shown in Figure 2. While the students were only presented the level of agreement to select (and they could furthermore only select one answer for these and any remaining questions), numbers have been assigned here on a 0 to 4 scale for reference where 0 indicates that the student did not agree at all with the given statement while 4 indicates that s/he agreed to an extremely large extent. Using this scale, the mean and standard deviations of each set of responses is also shown in Table 3.

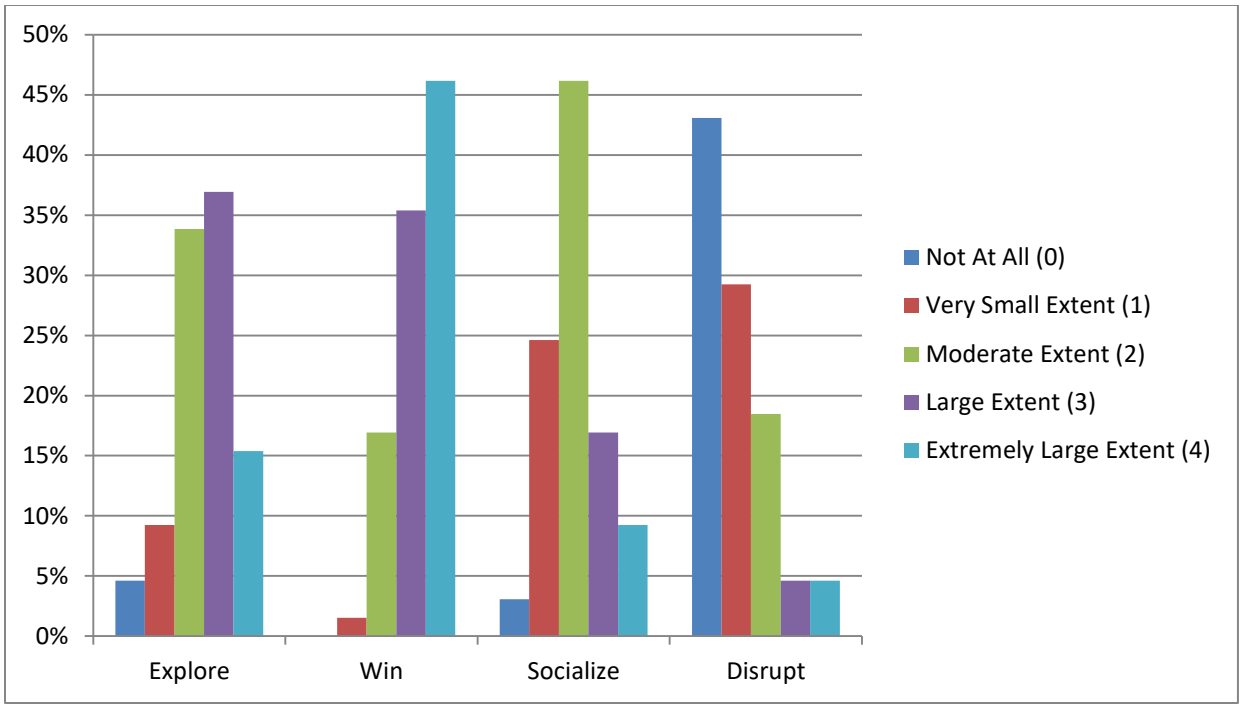

Figure 2: Self-identification with players from Bartle's taxonomy (N = 65)

Table 3: Mean and standard deviations of groups response sets from Figure 2

	Explore	**Win**	**Socialize**	**Disrupt**
Mean	2.49	3.26	2.05	0.98
Std Dev	1.02	0.80	0.96	1.11

From this, one of the key observations of this work was derived. Namely, within the present set of students, most of them play a game to win and to a lesser extent explore and socialize. Relatively few meanwhile play to disrupt others. Using these results, it can be deduced that *meaningful* challenges and goals would most likely best motivate such students.

Activities that encourage exploration and socialization (beyond the peer competitiveness of the leaderboards) could also be utilized in the future but would be a lower priority. Activities that involve disruption of others' learning are not as likely to motivate this set of students and could also be problematic to implement if they adversely affect the learning of the students whose learning is disrupted.

4.4. Gamification Impact

With the previous sections completed as context, students next indicated to what extent they agreed with statements about gamification making experiences more enjoyable, being helpful in their learning, etc. A selection of these results is shown in Figure 3, with the corresponding mean and standard deviation values shown in Table 4. Within these and the following section, response sets mostly followed a normal distribution with a standard deviation around 1, and no strong bimodal distributions were observed.

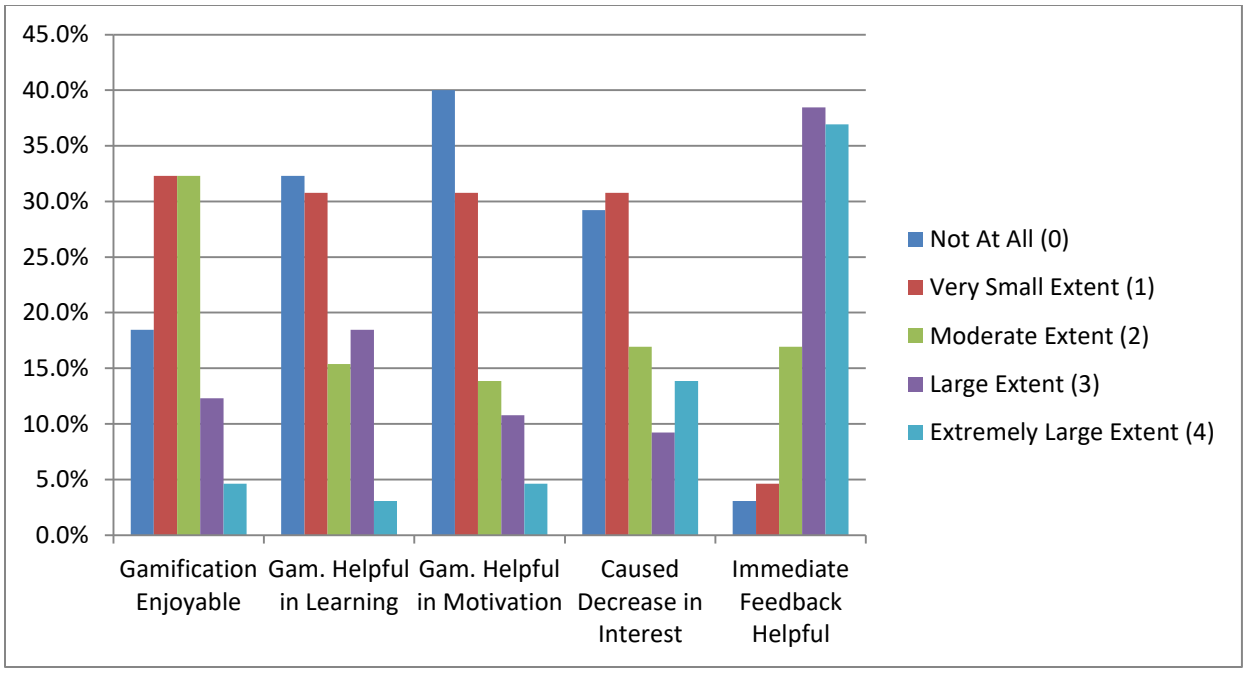

Figure 3: Perception of the impact of gamification overall and of feedback element

Table 4: Mean and standard deviations of groups response sets from Figure 3

	Gamification Enjoyable	Gamification Helpful in Learning	Gamification Helpful in Motivation	Gamification Caused Decrease in Interest	Immediate Feedback Helpful
Mean	1.52	1.29	1.09	1.48	3.02
Std Dev	1.08	1.20	1.18	1.37	1.01

With the current gamification implementation, these results indicate that the students perceived the gamified aspects of the course to have a small positive impact for most, but also that gamification did cause a small decrease in interest for some as well. The aspect that students thought was most helpful was when immediate feedback was provided, often in the context of Moodle quizzes where they could quickly try attempt the quiz again and feedback was provided based on students' responses. This coincided with students' response to another question that inquired whether students preferred online homework (automated quizzes), traditional homework on paper, or a blend of the two. Roughly 75% of the students expressed that homework should be a blend, while 17% thought it should be all online, and 8% thought it should all be done on paper.

4.5. Helpfulness of Gamified Elements/Activities

The last set of questions inquired about how helpful students thought various gamification activities/elements were or would hypothetically be towards their learning. The results of these can be seen visually in Figure 4 and the mean and standard deviations of the sets can be found in Table 5, where breakdowns of hypothetical and actual averages are calculated when appropriate.

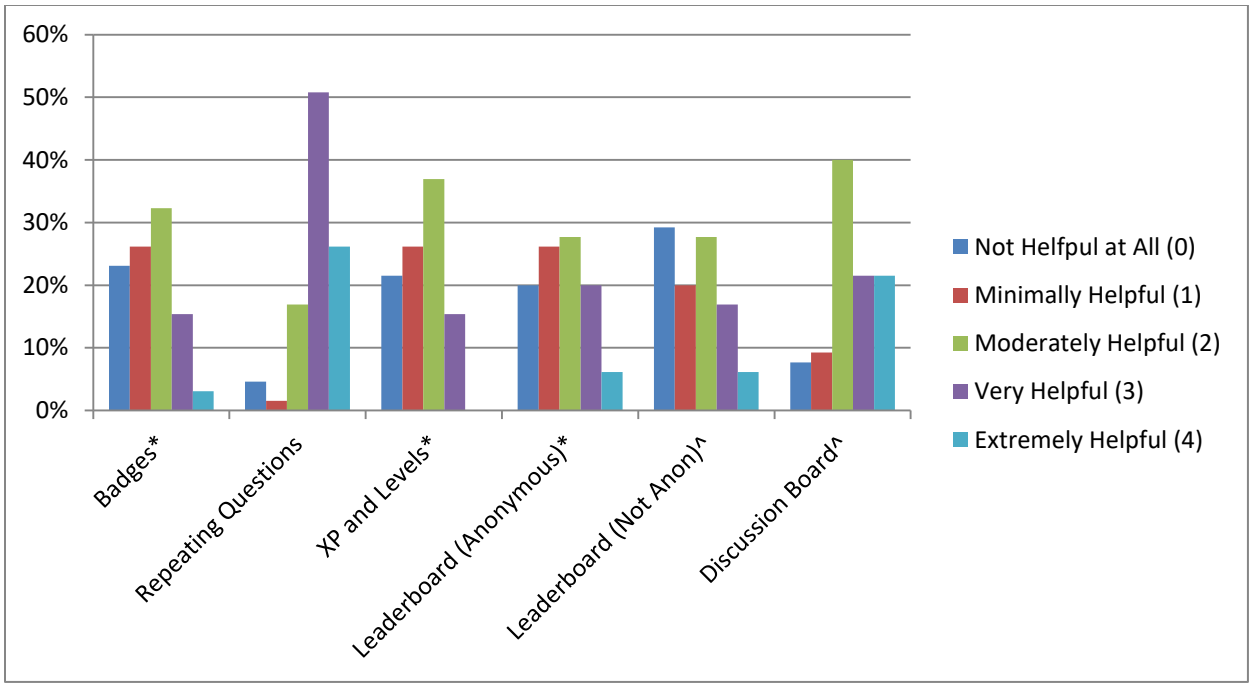

Figure 4: Perceived helpfulness of gamification activities (N = 65; * indicates a mixture of actual and hypothetical between the four courses from fall 2016; ^ indicates all hypothetical)

Table 5: Mean and standard deviations of groups response sets from Figure 4

	Badges	**Repeating Questions**	**XP and Levels**	**Leaderboard (Anonymous)**	**Leaderboard (*Not* Anon)**	**Discussion Board**
Mean	1.49	2.92	1.46	1.66	1.51	2.40
Std Dev	1.11	0.96	1.00	1.19	1.25	1.16
Hypothetical Mean	1.53	N/A	1.56	1.88	2.92	1.46
Actual Mean	1.36	2.92	1.43	1.59	N/A	N/A
Difference	0.17	N/A	0.13	0.28	N/A	N/A

From these results, it was observed that repeating questions was deemed the most helpful activity. Other activities were also perceived as helpful but to a lesser extent, with experience and levels being the lowest. From the purely hypothetical questions, students seemed interested in the idea of a discussion board, but overall they were less interested in a leaderboard that showed their names as compared to an anonymous leaderboard. Based on the comments from the survey, the leaderboard with names might even de-motivate students. Lastly, the hypothetical responses tended to be slightly higher than the actual results so instructors could use this information to only pursue those areas where there was a strong interest.

4.6. Overall student perception

In addition to the questions above, students were asked several open-ended questions throughout the survey about why they thought gamification did/did not help them with their learning and/or motivation, why they thought certain activities were more or less helpful, and what ideas they had to improve the gamification of courses. The most common comments that students collectively mentioned at least several times were:

- Leveling up without some associated end goal or comparison to others is not generally a strong motivator.
- There was a small amount of discussion between students about how they were doing compared to one another in terms of levels, often partly in a joking manner.
- Gaining extra credit as part of the gamified activities would be a useful motivational mechanism.
- Some students are still confused about what gamification is; they confuse it with specific activities (e.g. required pre-lecture quizzes), think that it should be an actual game, or assume that anything online is automatically gamified.
- Quick feedback is viewed as very beneficial to the learning process as is the ability to take quizzes multiple times.

Meanwhile, more isolated comments of note indicated that at least some students:

- Are cognizant of the limitation of multiple choice questions in someone's learning.
- Think you should be self-motivated or motivated solely by grades, not gamification.
- Recognize that there is a cost-benefit to using gamification in terms of the instructors' time.

4.8. Limitations of current gamification setup

Gamification, in its currently implemented form, was rather limited in scope within the four courses. The only aspect of the course that was gamified was a portion of the students' online experience in Moodle via their ability to gain experience points and level up, compare their XP with other students' via a leaderboard, take quizzes multiple times and gain feedback from them, and in some cases earn badges for completing certain topic quizzes. Table 6 compares this list of gamified aspects to a presently-available gamified software, DuoLingo [8]. As can be seen, there are many ways that gamification could be expanded just within the online experience. The in-class activities could also be gamified in similar ways (e.g. students gaining XP for attending class). Lastly, it is important to note that within EGRS430, the experience points and levels were not properly enabled and thus did not work throughout the semester. In EGEE320, students saw the levels but there some students that did not know that they could view the leaderboard. In all classes, gamification was not truly implemented enough to make any conclusions from the results.

Table 6: Comparison of gamified aspects of the courses as compared to those by a presently available gamified software, DuoLingo

Gamified Aspects Implemented by Both	**Gamified Aspects Implemented by DuoLingo but Not by Instructors**
• XP and Levels • Leaderboard • Badges by Topic Area • Quizzes with the Ability to Take Multiple Times	• Send Messages to Peers • Participation Streaks (Number of Days in a Row) • Automated Encouragement Messages • Algorithm to Show How Learned Material Faces with Time • Overall Proficiency Based on Ability to Complete Activities • Option to Strengthen Weak Topics • Option to Take Timed Review Quizzes • Unlocking New Topics Based on Previously Learned Items • Ability to Earn Money-Like Credit to Unlock Features Such as Extra Topics, Change the Mascot's Clothes, Etc. • Ability to Take Progress Quizzes

5. Summary and Future Research

In conclusion, this paper has described how various engineering course activities were modified to incorporate game-like elements and the results of a survey that examined how students did or did not think that gamification impact their motivation and learning.

For students, it seems that time and time management is a bigger issue than motivation. Therefore, gamified (and non-gamified) elements of courses will likely have the most impact if they address these issues. Overall, students viewed gamification on average as minimally helpful. Based on the Bartle taxonomy results, this particular set of students should have been most motivated by achievement-based activities and meaningful goals. Unfortunately, the experience points and levels were not viewed as meaningful by a number of the students based on their comments, so other goals should be identified in the future. Other conclusions cannot be drawn at this time since gamification was only implemented in small ways in the courses.

One future opportunity is to develop a concept map-like interface to help students understand their progress through the course information (which would hopefully be motivational) *and* gain insight as to how topics are related to each other. This was attempted in Moodle by organizing the semester by topics in spring 2016, but removed the milestone aspect which helps students gauge where they should be when a course is organized by semester week/date. As such, an alternate way of implementing the interface would need to be explored.

The next step in this research is to increase the level of gamification in the courses and see if there is a change in the perception about it. Examples of such expansion include developing more meaningful goals/challenges, utilizing new Moodle plugins such as "Stash" (which allows instructors to include specific items at different locations of the gamified content, such as lecture notes, for students to collect) to help students "explore," and incorporating gamified discussion boards to motivate students via more social interaction. In addition, as suggested by many

students, tying the experience points and/or levels to the student's grade in some way (e.g. bonus points) may help improve student engagement.

Another aspect that would be interesting to study would be whether gamification in some courses adversely affects non-gamified courses (i.e. if a student completes a gamified course, are they then less motivated in a traditional, non-gamified course than they would have been otherwise?). Lastly, while these surveys are useful, they are just the students' perceptions. Ultimately, some measurement of the students learning needs to be done (e.g. via comparison of exam questions) to determine if there is a meaningful gain when gamification is used.

References

[1] Deterding, Sebastian, et al. "From game design elements to gamefulness: defining gamification." Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. ACM, 2011.

[2] Barata, Gabriel, et al. "Engaging engineering students with gamification." Games and Virtual Worlds for Serious Applications (VS-GAMES), 2013 5th International Conference on. IEEE, 2013.

[3] Hamari, Juho, Jonna Koivisto, and Harri Sarsa. "Does gamification work?-a literature review of empirical studies on gamification." System Sciences (HICSS), 2014 47th Hawaii International Conference on. IEEE, 2014.

[4] Huang, Wendy Hsin-Yuan, and Dilip Soman. "Gamification of education." Research Report Series: Behavioural Economics in Action, Rotman School of Management, University of Toronto (2013).

[5] Simões, Jorge, Rebeca DíAz Redondo, and Ana FernáNdez Vilas. "A social gamification framework for a K-6 learning platform." *Computers in Human Behavior* 29.2 (2013): 345-353.

[6] Kiryakova, Gabriela, Nadezhda Angelova, and Lina Yordanova. "Gamification in education." Proceedings of 9th International Balkan Education and Science Conference, 2014.

[7] https://www.unionlearn.org.uk/common-barriers-learning, Accessed February, 12, 2017.

[8] https://www.duolingo.com, Accessed February 12, 2017.