# Introduction of Gamification in Common Core Engineering

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***Abstract*** *–The Schulich School of Engineering is currently redesigning its first-year curriculum and will be piloting a number of new approaches in the Fall15/Winter16 academic year. In addition to experiences with flipped classrooms and online professional skills modules, we will be adding a component of gamification to one of our first-year courses. Gamification is the application of the typical elements of game playing (e.g., point scoring, competition with others, rules of play) to education in order to encourage engagement with the course material in a compelling and familiar way. This paper will describe the following: underlying game mechanics; game design techniques; and how these can be integrated into/applied to/used to enhance engineering education. Approaches covered will include the following: using experience points to replace traditional grading; user -generated content; and a tiered rewards system giving students choices that enable them to strategically manipulate their relationship with the course material. Gamification has the ability to let students make choices based on their strengths. Given the four-player archetypes of Explorer, Achiever, Socializer, and Predator, it is important to include incentives that motivate each type of student. Effective gamification achieves not only engagement, but it also attends to cross-archetype engagement. That is, the Socializers will constantly inform the other students of achievements that have been discovered by mainly the Explorers, but when Explorers receive a new achievement, they will feel compelled to become a Socializer and tell everyone of their discovery. Predators might earn an achievement for passing a certain number of people on a leaderboard or for creating a question that was very challenging. They will then feel a sense of ownership and likewise will play the role of Socializer and inform others of their achievement.*
*Examples of ways that gamification can be applied to current practices will be provided.*

***Keywords: Gamification, Cross-archetype engagement, User-generated content***

## 1. INTRODUCTION

Engineering education faces a number of challenges, which requires schools across Canada to take a closer look at assessment and evaluation. In an effort to take advantage of elements of game playing with the aim of encouraging interaction with others and the creation of course material, gamification has become an area of interest and a current focus of curriculum redesign. This paper touches on new directions in engineering education (one of which is gamification). The paper then describes a number of findings on the impact of gamification, the mechanics of gamification, and the way in which we envision gamification in our curriculum redesign.

## 2. DIRECTIONS AND IMPACT

### 2.1. New engineering education directions

In a keynote presentation during the 2014 Reimagine Education Conference held at the University of Pennsylvania, Dean Geoff Garrett of the Wharton School commented that the three main developments currently transforming higher education were flipped classrooms, adaptive e-learning, and gamification. These comments were reflected in the two submissions that were deemed as being the most innovative at the 2014 Reimagine Education Conference. The first was PhET Interactive Simulations [1], online learning modules for K-12 that originated through the work of Nobel Prize recipient Carl Wieman when he was at the University of Colorado Boulder. The second was PaGamO [2], a multi-student social gaming platform that was developed for the first ever MOOC made in Chinese.

The fact that a social gaming system was highlighted out of submissions received from 427 universities and enterprises from 43 countries is indicative of the significant potential that exists when gaming is applied to the learning process. The pedagogical foundations that enable this are numerous and include student motivation, practice and feedback, and the development of mastery [3]. Not only does gamification provide student

motivation, but also if designed correctly, it can provide timely and targeted feedback to the student, which assists in the learning process. Through this process, students are able to acquire the component skills for their topic of study. By designing teaching and learning activities that require the integration of these component skills, the students will be better guided down the path of mastery.

Referring to the work of Hattie [4; 5], gamification can be designed to include techniques that have been identified as being highly effective in higher education. These include the following: feedback; spaced versus mass practice; self-questioning; cooperative learning; goals through progressive difficulty; student concentration / persistence / engagement; and time on task. The effective (or appropriate) integration of these techniques highlights the importance of the game design process itself (Fig. 1). One of the goals of game design is to create conditions whereby many of these techniques are integrated into the teaching and learning activities in order to achieve a positive outcome.


Fig. 1. Effectively gamifying a concept [11].

## 2.2 Impact on educational experience

Gamification can be instrumental in structuring an educational experience. As mentioned above, gamification runs parallel to pedagogical goals in higher education such as progressive difficulty and student persistence. Sequencing knowledge and quantifying what students need to learn and achieve can be embedded via gamification. Students should not only complete and understand concepts at each stage of the learning, but they should also be motivated to push to the next stage. Examples of elements of game mechanics classified under 'self-elements' (complete) and 'social elements' (push) can be seen in Figure 2 [11].

Examples of Game Mechanics
(Self-Elements vs. Social Elements)

| Self-Elements (Complete Stage) | Social Elements (Push Stage) |
|---|---|
| Points | Leaderboards |
| Levels | Virtual Goods |
| Trophies/Badges | Interactive Cooperation |
| Virtual Goods | Storyline |
| Storyline | |
| Time Restrictions | |
| Aesthetics | |

Fig. 2. Game mechanics [11].

# 3. SOLUTIONS CONSIDERED

Three main gamified solutions were considered:

1. *Student Assignments*: A socially anonymous system that requires students to create a question each week, and answer five of their fellow classmates' questions from the previous week.
2. *Student Notes*: A socially anonymous system that requires students to author an entry into an online notes database each week, and review and rate five of their fellow classmates' entries from the previous week.
3. *Umbrella Points*: An overarching engineering curriculum experience-points system which would require the professor from each course to define ways in which students could earn experience points, and also the rewards that could be unlocked when students have gained enough points. These points could be applied to any course reward a student chose, regardless of which course was the source for awarding the points.

Due to the large scope of *Umbrella Points*, *Student Assignments* and *Student Notes* were chosen from the above list given that they can be developed and executed in time for the Fall 2015 semester. Both *Student Assignments* and *Student Notes* are similar in terms of implementation; the main difference between them is the nature of the student-generated content. As such, the following describes *Student Assignments* but applies equally to *Student Notes*, unless otherwise noted.

## 3.1 Student Assignments

For the following description, the terms *Author* and *Evaluator* are defined as follows. *Author* refers to the student who creates a question, and *Evaluator* refers to the student who evaluates the question.

The intended use of *Student Assignments* will be to replace the weekly assignments in a course such as Calculus I or Introductory Computer Programming. It will usually be weighted at or near 10% of the final grade, and the grading will be pass/fail based on whether or not a student completes the minimum work required; the quality of contributions will not be graded. The gamification of the system will incentivize students to produce higher quality work.

The process of initiating and customizing the system for a particular course will require advanced input from the instructor. To initiate the system, the instructor will log in

and create an underlying base structure of the course material. This provides the backbone that will be used by the software to which content can be attached, and will look somewhat similar to the table of contents from a textbook. The instructor will also enter an initial set of questions that students will answer during the first week. This initial question set will provide students with an example of the types of questions that can be generated in the course.

Once the system has been established, Authors will be required to log into a website to complete their work. Weekly work will consist of two distinct parts: content creation and evaluation. Content creation involves the student Author creating at least one multiple-choice question, complete with possible answers, and specifying which of these responses is the best choice. Student Authors will also classify the section to which their question pertains, as set out by the instructor as part of the initialization procedure.

The second part is based on evaluation. Student Evaluators will review a minimum of 5 questions written by their peers. To assess a question, students will first answer the question, then be informed of whether or not they answered correctly, and finally will be provided with the correct answer if they answered incorrectly. The student Evaluators will rate each question on a scale of 1 to 5 for both quality and difficulty. The students will also respond to 3 queries about each question:

- Is this question helpful?
- Is this question unique?
- Is the answer to this question correct?

If more than one student flags a question as being incorrect, that question will be placed under review by the system. Students will have the option to earn bonus RL (Real Life) points (points awarded to players from a gamified system for use outside of that system), and certain badges, by reviewing these flagged questions and providing feedback to the Author. Questions that students can't come to an agreement on will either be sidelined or flagged so that the instructor can review them, depending on the instructor's preference.

When a student logs into the system during the second and subsequent weeks, the system will provide them with a report that details the results of their performance in the previous week, awarding them with performance-related bonus RL points, should they deserve them. The software will automatically generate this report using the data collected during the previous week. The report itself will be a mixture of highlights from the work performed during the previous week. It will tell students if they are doing well in certain categories, such as writing quality questions, as well as inform them of areas they could improve on, such as if their questions are consistently too hard or too easy.

Data collected each week will have several triggers for both system maintenance and content quality. These triggers will involve the quality of questions, but they will also gauge the quality of feedback given by student evaluators. The software will compare a specific evaluator's feedback against the feedback provided by their peers. In their weekly reports, they will be informed of whether and how their feedback differs from the average.

In the manner that the system acts as a social buffer for the students, it will also act as a buffer for the feedback students receive from each other. At the conclusion of the first week, the system will start to adjust the evaluations given by students according to their rating history. For example, academically strong *Evaluators* might always rate questions very low on difficulty, due to their own proficiency with the subject material. In cases such as this, the software will adjust these ratings before applying them to the feedback that the author receives. These adjustments will be more aggressive if a student tends to rate questions consistently above or below the average of their peers.

Students who choose to answer more questions than are required, or students wishing to review previous material can specify which categories of questions they wish to review, and the system will provide them with questions that have a high rating.

RL points will be awarded for each task completed, whether it is creating a question or answering a question. The vast majority of the points given out will be associated with the required weekly work, i.e. writing one question and answering five questions correctly. Going beyond the minimum weekly work, either by writing additional questions or answering additional questions, will award students with bonus RL points. However, the quantity of extra points given out for these activities will be less than for the weekly work and will have diminishing returns.

Other bonus RL points, which will not be functionally different from the RL points as described previously, will be awarded in a variety of ways. Answering consecutive questions correctly will result in a "combo", and a small but ever growing amount of Bonus RL points will be awarded for each question. Additionally, after answering their 5 questions for the week, students will be prompted

to complete a review question from the previous week for additional bonus RL points. Bonus RL points are also given out in the weekly report and these bonus points will be associated with the 3 leaderboards on which the student ranks the highest for that week.

### 3.2 Achieving the goal; the meta-system

While the main motivator for gamifying a course is to encourage engagement and student motivation [3, 4], a secondary benefit of the system is the user-generated content. Due to the large class sizes in the first-year program at the Schulich School of Engineering, the system will generate a large database of user-generated content. Assuming that the primary goal of student motivation is achieved, the results will create useful content for the students while potentially lowering the workload of the professor.

Recent work in gamification is largely centered on defining key techniques of gamification and measuring their effects. In our minds, while there is some benefit to measuring the effect that a progress bar has when placed at the end of each sentence in a textbook, this practice is a gross oversimplification of the way gamification can and should work, and is akin to squirting lemon juice in someone's eye to determine whether or not he or she likes lemon meringue pie.
Badges, leaderboards, points, reward scheduling, and a few of the hundreds of tools in a game designer's tool belt are only effective when used in an appropriate context, and more importantly, when used in the an effective way.

### 3.3 The importance of social anonymity

As has been demonstrated in many ways on the internet, from public forums to the foul-mouthed, trash-talking children on Xbox live, social anonymity grants people the freedom to act with less fear of negative repercussions. While this type of behaviour is generally viewed as undesirable, the freedom created by anonymity can allow people who are generally less competitive due to introversion to compete in an environment with fewer social barriers.

To achieve social anonymity while maintaining a persistent sense of community and competition, each student username will be randomly generated by the system. This will be uniquely true (and known) for each student. This means that each week while looking at the leaderboards or evaluating questions, they will be able to associate that content with a particular profile. This will create a socially consistent community for them to interact with, but the actual student behind each profile will remain private unless a student chooses to reveal his/her identity. Allowing a student to "go public" in this fashion provides the best of both worlds; it allows Achievers to still receive the recognition they desire while allowing others who wish to remain anonymous to still do so.

### 3.4 Badges

In this system, badges (Fig. 3) will be hidden from players until awarded to them, and they will have varying amounts of RL points attached to them. There will be a large number of badges in the system, and when players earn one, it will be added to their list of badges on their profile page. Players will also be able to display their favourite badges along with their avatar used for the leaderboards.

All three archetypes will benefit from this implementation of badges. Once the Explorers have been onboarded they will try to find badges that have not yet been discovered. Socializers will enjoy seeing what badges others have acquired; they will also enjoy learning about the badges; and then they will look forward to sharing that knowledge with their peers. Badges themselves are a symbolic representation of achievement, and therefore intrinsically reward the Achiever archetype.


Fig. 3. Example: Badges at Purdue University [9].

### 3.5 A New Take on Leaderboards

Whether or not leaderboards (Fig.4) are beneficial as a gamification tool is currently a matter of some debate among the gamification community. Many people think that leaderboards are demoralizing to players who are not competitive in nature or who are not good at competing. Chris Hecker (2010) has argued that the use of leaderboards can actually take away from the intrinsic rewards the system provides. We believe this can be true, especially where leaderboards and points system are presented as the primary goal of an activity. This is why the proposed system will only use leaderboards as a method for positive reinforcement of certain behaviours.

The leaderboards in the system are only accessible through a student's profile page, and only displayed to a student when they enable it. The exception to this is the weekly report, which includes only the leaderboard on which the student was ranked highly.

If leaderboards can have a negative effect on participants, we believe this is partially attributable to the fact that leaderboards tend to stagnate over time, making it harder to move up in rank as the participants become more entrenched. Our system will intentionally dilute the importance of leaderboards by creating many categories of leaderboards on which students can be ranked with certain leaderboards that are diametrically opposed to each other. Another strategy to reduce the focus on competition will be to the reset the leaderboards at regular intervals. Not only will there be a myriad of leaderboards, but many of the leaderboard categories will be blatantly obvious in their irrelevance, creating many humorous comparisons for students to make with each other. This will appeal to the Socializer archetype.

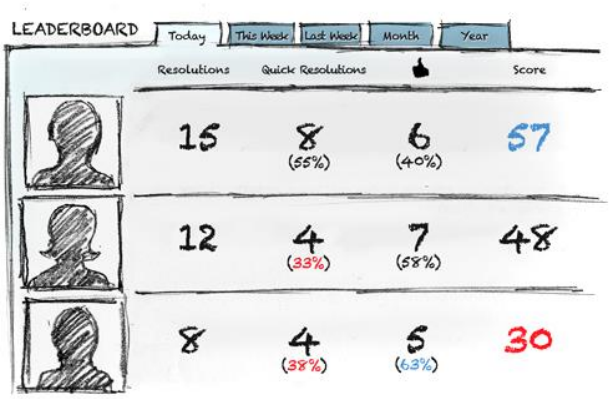


Fig. 4. Leaderboard sample [10].

### 3.6 Progress Bars

Progress bars will be used throughout the system for anything to which they can be applied. Being that progress bars are not actual game mechanics and simply a way to graphically represent how close a certain task is to completion, there is little reason not to use them, given the several studies [5, 6, 7] that have confirmed the positive effect they have on participants.

### 3.7 Real rewards for real points

RL points will be used to purchase rewards of a student's choice. These rewards will be tangible rewards that change the way a student participates in the course. This will allow students to choose rewards that give them an advantage in a certain area of the course where they feel they need it most. While the exact rewards and the costs of these rewards will vary from course to course, the following list describes typical rewards:

- Extra time on a test
- Bonus marks on their next assignment
- Exemption from a lab
- Skipping a question of their choice on a test
- Allowing them to bring their textbook into a test

While some might argue that this gives an unfair advantage to certain students who earn more points than others, we feel that this advantage is no different from that of a student who obtains a 90% average in the course work has as compared to a student with 50%. In other words, with a portion of the course work grades being assigned to this system, and the fact that the system is pass/fail in terms of grading, these two hypothetical students' grades will be closer to each other in this scenario. Thus while the 90% student may score slightly higher than they might have, the end result in regards to grade distribution is the same. Furthermore, the way that points are awarded will be carefully balanced so that even a modest effort by students will enable them to collect a substantial number of points. The key is balancing the points awarded so that performance is weighted lower than participation, but not so low that it discourages performance.

### 3.8 A word on cheating

Gamification has a lot to do with incentivizing people to interact with a system in a desired way. In the modern world, students can (and frequently do) share answers to assignments with each other. Solutions need to be designed with this in mind. The two most obvious incentives for cheating are avoidance of work and acquiring better grades.

The very nature of gamification helps reduce a student's desire to cheat in order to avoid work. A well-gamified system is an activity that is enjoyable in and of itself. If this is achieved, students complete the work mainly because they find it to be an enjoyable experience.

On the other hand, students who cheat in order to get higher grades might be compelled to evaluate each other's questions in such a way as to gain an advantage over others in the course. Students who try this will quickly learn that, while the system may seem to incentivise this behaviour on the outset, it will in fact punish it. The system will track the standard deviation of each student's evaluations, and evaluations that deviate largely from those of their peers will be disregarded by the system.

Furthermore, specific leaderboards for giving good evaluations will be used, meaning students who give poor evaluations will not be able to benefit from the bonus RL points given out for that leaderboard, and they will also not earn any of the badges associated with giving good evaluations.

### 3.9 Measureable Outcomes

Measuring the outcomes of this project will be accomplished in two ways. Since the system will track and record every aspect of each student's behavior, this data can then be compared to their grades on the final exams, as well as their grades in other courses. This will ultimately help us answer a variety of questions, including, but not limited to the following:

- What correlation is there between good performance in the system, and good performance on the final exam?
- Is there an association between a certain player archetype and exam scores?
- Do tangible rewards for a gamified system motivate all of the player archetypes?
- Is the system engaging a demographic of student that is generally less engaged with their education?

Surveys will also be conducted to measure student perception of the gamified course such as to determine if students perceive a motivational benefit from it. In addition, the surveys will ask students to define their player archetype. With this information, it will be possible to compare student behaviour within the system to our expected sets of behaviour for each archetype. Furthermore, the survey will assist in measuring how effective the system is at motivating each archetype.

## 4. CONCLUSION

Gamification of education is a new educational approach that uses game mechanics to influence student behaviour and motivation. The Schulich School of Engineering will be piloting gamification in a number of first-year engineering classes in the Fall of 2015. The hope is that "with the successful application of suitable gamification techniques, the delivery of the information can transform a simple or mundane task into an addictive learning process for the students. For students, gamification serves the purpose of minimizing negative emotions that they usually encounter in traditional forms of education. It lets them approach knowledge and skills, using the learn-by-failure technique that is popular in game-like environments, without the embarrassment factor that usually forms a part of classroom education [11]."

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## APPENDIX A: Terms used in the paper

RL (Real Life) points: Points awarded to players from a gamified system for use outside of that system.

Achievers: Advancement, Mechanics, Competition

Socializers: Socialising, Relationship, Teamwork

Explorers (Immersion): Discovery, Role-playing, Customization, Escapism