Improving Student Attitudes Toward the Capstone Laboratory Course Using Gamification

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Gamification, or the introduction of game-like mechanics into non-game contexts, has received increasing attention recently, largely for its perceived ability to motivate participants into desired courses of action by making mandatory or mundane tasks rewarding in some way. Examples of this in the business world include frequent flyer reward programs, social programs such as FourSquare or Facebook Check In, and app-type gamification of to-do lists, weight-loss programs, or exercise programs.

Application of gamification to education is a logical extension, as it has the potential to motivate students to perform extra learning tasks that they might not otherwise do by couching those tasks in the larger context of a game, or by providing small but tangible non-grade rewards for their completion. To study this phenomenon, we chose to overlay a collaborative team-based game context over the traditional senior capstone chemical engineering laboratory course. As a laboratory course, the structure is such that students are naturally clustered into teams working on different experiments. This allowed us to easily divide the students into randomly assigned teams ('guilds' in our example) that were united by a common purpose – completing their major experiment. By completing required tasks such as lab reports and presentations, students earned XP (experience points), which translated directly into a traditional grade. In addition, other, optional tasks were added that could earn a student additional XP (effectively extra credit), but also another resource, called Reputation. While reputation did not affect a student's grade directly, by working collectively with other students in their guild, students could pool Reputation to effectively 'win' the game. In this context, the guild with the most reputation at the end of the semester was allowed to choose from several rewards (dinner out with the faculty, the ability to choose an experiment the following semester, a small boost to one of their best grades, etc.). Optional tasks were ones that the instructors thought would benefit the students, but in practice, without incentivization, few students attempted. Examples include peer evaluation of their work, seeking out and using external references in their writing, and performing data analysis during the course of the experiment and using that information to modify their experimental plan.

Both pre- and post-course surveys were carried out, which collected data on the students' experience with a multitude of game types, as well as their personal habits. Additionally, their attitude and perceptions about gamification and our particular implementation were surveyed both prior to the start of the class and after the semester ended to compare differences. After one semester of implementation, comparison of scores on lab reports from a non-gamified offering of the class with the gamified version showed no statistical difference. However, the student participation in incentivized tasks was high, and showed a broad appeal across different levels of academic performers. All students participated at least at some level, even though the game tasks were completely optional. Most students reported that it was a refreshing change to a standard course offering, and when polled, 86% (43 out of 50) wanted to continue with the gamified version in the spring semester.

1. Introduction

The capstone chemical engineering laboratory appears to be a somewhat polarizing course. Some students approach the course with numerous preconceptions, such as the course is too much work or that the experiments are dry and bland. Furthermore, in our experience, students typically fail to do simple tasks that can enhance the quality of their lab reports, typically due to running out of time in the preparation of said report. In an attempt to change these trends we notice in our students, many alterations to the laboratory course have been integrated into the course since 2010, including the integration of experiments based on emerging technology and moving to a new laboratory space. However, these elements are costly and not necessarily able to be integrated at another university. As such, we felt changing the way the course was conducted could be a cost-free way to generate students excitement toward the lab. To that end, we devised a new game structure to overlay over the existing assignments.

The intent of the game is to increase student interest and engagement in the course, leading to improved attitudes toward the laboratory and increased knowledge retention. Furthermore, the gamification elements were used to incentivize certain actions that we believe would be beneficial to students' future careers, be they in academia or the work force. Hopefully, students would perform the extra tasks and allow them to become habit, contributing to their future success. The game was conducted during the Fall 2012 semester using a class of 51 seniors. The students were predominantly 20-22 years old, and there were 14 female students in the class.

1.1 Gamification as an Educational Tool:

Over the past several decades, video games have become increasingly mainstream. Today's college students have grown up in an age shaped by gaming. They are not old enough to know a world without in-home game consoles, and the recent surge in popularity of mobile and social games have exposed gaming to the masses. As such, in recent years, educators have been trying to utilize the core mechanics of games to enhance their lessons. This technique is known as gamification, which is the application of game-based mechanics, aesthetics, and thinking to engage and motivate people and promote action and problem solving[1].

In defining gamification, it is important to define the difference between games and play. Play designates a more free-form experience, whereas a game is a more structured activity with rules[2]. Thus, the distinction between a game and gamification lies in the completeness of the game experience: a game is considered a complete gaming experience, whereas gamification will select appropriate elements of game thinking to utilize. In terms of both games and play, the key action is that the tasks are voluntary; if the tasks are required, it ceases to be playful and is more akin to work[3].

Since 2010, there has been extensive research into what exactly constitutes effective gamification of academic courses[4-9]. These studies have many common game elements to be effective in the classroom. The first common feature is that gamified classes have a clear goal. In some cases this can be as simple as earning a grade in the course. Next, a series of rules is put in place to direct students toward reaching the aforementioned goal. Another common feature of games that is effective in teaching is cooperative and competitive elements. Perhaps students

will have to cooperate with other students to accomplish the goal while competing with others. In both cases, students are motivated to achieve the goal.

Games and play can be effective motivators based on people's emotional responses to games. Success in games has been shown to evoke positive emotions that are greater than those in daily life[3]. Furthermore, many games judge success based on the acquisition of resources. This mentality can be translated to courses. Students can earn a resource as they successfully complete assignments, increasing their grade as the semester progresses. Earning things based on successfully completing assignments, as opposed to losing things based on poor performance, can alter student perceptions of the class and give them a more positive attitude toward learning[9]. While it is still difficult to judge if adding game elements actually contributes to student learning or retention, and while gamification is not a "magic bullet" that can be applied to every course to equal effect, it can allow students to associate the course material with positive reinforcement[1,10]. Additionally, the novelty of the teaching style can be memorable to students[11].

2. Previous Laboratory Organization

In past lab offerings, students would perform three of a possible seven experiments in one semester. Each student performed two experiments that lasted for three lab periods and one experiment that lasted for six lab periods. Partners were assigned at random, and each experimental group functioned independently. In the second semester of lab, students performed three experiments from a different set of seven.

For each experiment, students prepared a pre-lab report that was graded based on understanding of the experimental theory, an experimental plan, and a safety review. Students would prepare a variety of reports for each experiment, including academic-style written reports, business memos, formal PowerPoint presentations, and poster presentations. After their experiment and report, the students completed an auto-rating form in which they graded the performance of their partners as well as themselves. All three of these components factored into students' final grade in the course. Each experiment received the same weight in the course (i.e. each set of pre-lab, report, and auto-rating are worth 100 points, so each semester is graded out of 300 points). All reports were submitted electronically using the free software Dropbox.

3. Gamifying the Base Laboratory Experience

The first step in gamifying the class was the introduction of a new point and level structure. Instead of earning a certain percentage of points on an assignment, students just accumulated total points, called Experience Points (or XP). Assignments and reports were as described above, only now each experiment was worth 1000 XP (for a 3000 XP total). Students began the semester at Level 1, and every 300 XP they earned increased their level by 1. While these levels did not necessarily correlate to letter grades to allow for grade scaling, students were told that the higher their final level, the higher their grade in the course will be. This method of gamifying a class has been used previously and has been shown to be effective[9]. It was thought that this would be effective for the laboratory class, as students would be encouraged by the desire to earn more points, rather than demotivated by the fear of losing points. Furthermore, it was hypothesized that the implementation of levels would motivate students by giving them more

periodic acknowledgements of their progress and growth.

In addition to the XP and level structure, another system of points was implemented to allow for rewards that did not have a direct impact on student grades. These points would prevent student extra credit from overwhelming the points earned from required assignments. Therefore, Reputation points (or Rep) were created. It was decided that Reputation would be the 'win condition' of the gamified class in order to give these points meaning.

Students were randomly split into six teams, which we dubbed their "Guild." This naming fit the medieval fantasy feel of video games like World of Warcraft and Skyrim that inspired the approach. It was also thought the terminology would resonate with a subset of the students used to gaming terminology. Rep served as a point total for each Guild, and students were encouraged to maximize their team's Rep through completion of the optional tasks discussed in the next section. Some of the tasks could be things that would benefit the students themselves (awarding XP, or points that counted toward their grade), while other tasks would award Rep, and thus help the larger guild as a whole. The team with the highest Rep at the end of the semester would "win the game," and have their choice of a reward. For the first run of this system, the three rewards were a pizza party, the ability to pick one experiment to do next semester, or extra XP equal to 10% of your highest lab report grade. It was hypothesized that the natural competitiveness of some of the students would motivate them to complete the extra tasks, and that the students in turn would motivate the other members of their teams to complete the tasks as well.

The terminology used in the game is compared to terminology more commonly used in classes is shown in Table 1.

Table 1. Summary of Core Game-Specific Terms

Game Term	Definition	Traditional Course Analog
Experience Points (XP)	Points that contribute to one's overall grade in the course	Grade points
Level	A value that increases as students earn more XP to give a greater sense of progression	Decile; letter grade (if highest level considered an A)
Guild	A group of students randomly assigned a common six-day experiment during the semester	Student team
Reputation (Rep)	Points that guilds amass during the semester; the team with the highest Reputation wins the game	Team points

3.1 Choosing and Incentivizing Optional Tasks

With the base level of gamification in place, optional, but beneficial, tasks that added richness to the game structure were included. When contemplating what to incentivize, the following criteria were considered:

1. The extra tasks should not be something traditionally graded, but still benefit students' understanding of the class and good laboratory practice in some way.
2. The extra tasks should not be dependent on skill, ensuring that everyone in the class could participate.
3. The tasks should be optional; a student should be able to complete none of the optional tasks and still be able to pass the course (and earn a high grade). If the tasks feel compulsory, the purpose of the game is defeated.

Using criteria 1 and 2, a list of tasks was generated. These tasks included actions students could take during their experiments (such as presenting evidence of intermediate data analysis), during data analysis (such as looking up examples in textbooks or asking specific questions to the instructors), while writing (such as peer editing or taking their draft to the university Writing Center), and throughout the semester (such as carrying a full experimental design from the first group of the semester to the last).

Criterion 3 was difficult to implement at first. It was undesirable to make all of the optional tasks reward XP, which translated directly into points and, hence, grades. Doing so made the optional tasks feel compulsory, and the extra points might skew the class grades by an unacceptable margin. It was also feared that if students were given ample and readily accessible means of accessing bonus points, then their efforts on the actual assignments, which are the core aspect of the class, might suffer, as they could make up for poor performance on the compulsory aspects of the class with the optional content.

3.2 Rewarding Optional Tasks

Students had the ability to earn Reputation for their Guild in several different ways, which have been summarized in Table 2 for ease of reference.

Table 2. Types of Optional Tasks

Task Type	Description	Possible Completion Frequency	Reward Type	Examples
Quest	Tasks that are designed to encourage quality lab reports	Once per lab report	Rep	Discuss your experimental results with an instructor before your experiment is over
Emblem	Tasks designed to encourage students to work as a Guild	Usually once per semester	Rep	Everyone in the guild is at least Level 8
Achievement	Tasks that reward students for doing more involved or special actions	Once per semester	XP	Complete each of the five available Quests at least once
Title/Ability	Bonuses that reward students for reaching certain levels	Once per semester	XP or Rep	Each Quest you completed is worth 20 extra Rep

Reputation was primarily associated with actions called Quests, which are tasks designed to teach students good laboratory report preparation habits. These tasks were to cite a piece of peer reviewed literature in your report, cite a textbook in your report not included in the laboratory documentation, present evidence of intermediate data analysis during your experiment, talk to an instructor about your data after your experiment was over, and have your written report draft critiqued by the Writing Center. Each of these tasks could be completed once per experiment, but multiple times per semester.

As mentioned above, it was desirable that a few incentivized tasks grant students XP to serve as extra credit (which we called Achievements). Achievements incentivized students to peer review their written lab reports, complete as wide a range of Quests as possible, and present data generated by previous experimental groups to enhance their own. Generally, Achievements required more effort and long-term planning than Quests did, and they could only be earned once during the duration of the semester.

While the competitive aspect of games was in place, an effort was made to facilitate cooperation and communication between students in the same Guild. This aspect of the game could prepare students for functioning on a large team made up of several smaller teams in the workplace. One way to do this was to incentivize students in the guild to collaborate on their large namesake experiment. As all members of the group would perform that experiment at some point during the semester, they were collectively encouraged to develop a broad experimental plan that could be carried out by the different sub-groups over the course of the semester. The last group would then use all of the accumulated data in their experimental report, and appropriately cite the other groups. Other team-based extra actions, called Guild Emblems, were also introduced. The Emblems were designed to reward students who functioned as a team with Rep. Tasks that earned Emblems ranged from everyone in the Guild reaching a certain Level to making an instructional video for one of the experiments to designing a Guild crest. These tasks required students in the same Guild to work together.

Additionally, taking another cue from role-playing video games, a Title system was added to give more meaning to the Levels. At certain Levels, the students could elect to change their Title, which would grant them and their guild certain benefits. For example, at Level 2, students could elect to become a Lab Squire or a Lab Apprentice. At higher Levels, Squires could select a new Title that could augment the Reputation earned from Quests, while Apprentices could either grant a small amount of XP or a large amount of Rep to their guild. The idea behind Titles was to create a scenario where students would have to interact with one another, strategizing and hopefully trying to balance their group and maximize the amount of Rep they earned in an attempt to win the game. This interaction may also encourage students to think about the class when they ordinarily would not, and also promote the game concept of gaining in power and ability as one progresses through a game. Furthermore, the element of Title choice was added to give students a sense of agency. Games rely on player choice frequently to help get the player develop a sense of ownership and become invested in the experience. By incorporating a Title choice, it was hoped that students would become more invested in the laboratory experience. For a more detailed explanation of these elements, the authors have prepared a comprehensive

rulebook available on request.

The method through which these different point values are combined into a Guild's final Reputation score is shown in Figure 1. All XP and Rep earned by students of a Guild are averaged together, and this final number is their current Reputation.
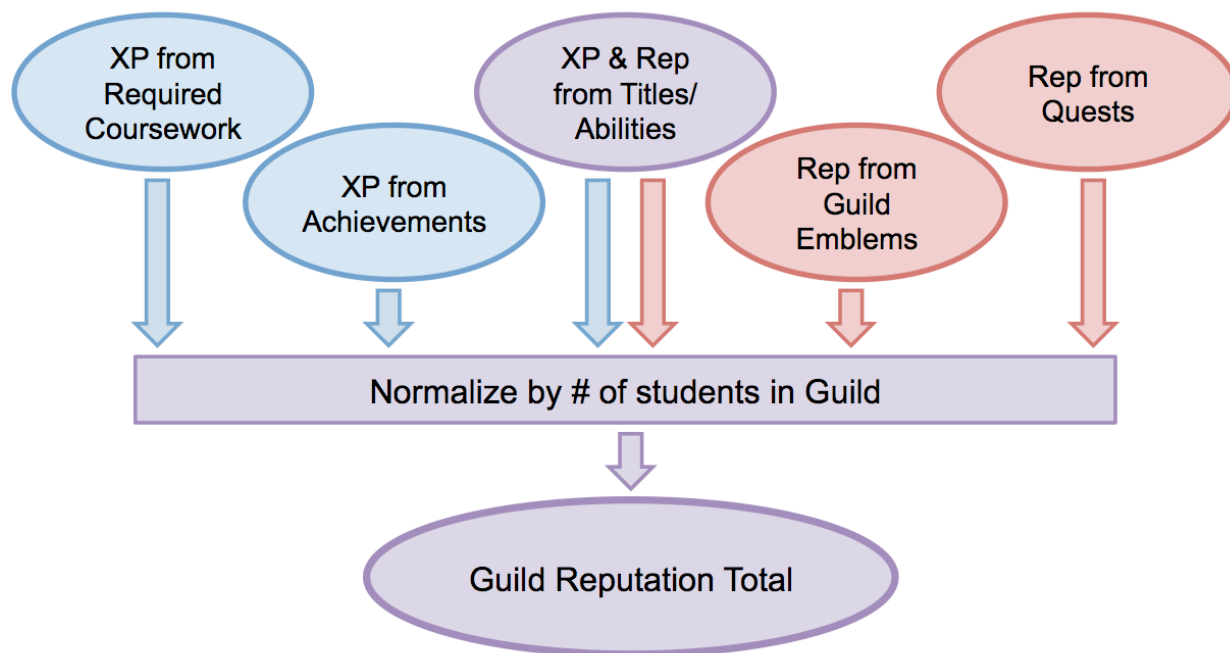

Figure 1. Determination of guild Reputation total. Blue tasks reward XP, red tasks reward Reputation, and purple tasks are a combination of both.

3.3 Tracking Student Performance:

In order to help students keep track of the extra tasks completed, each student was given a report sheet, called a Character Sheet. Character Sheets included grades for all required elements of the course, as well as Quests students have completed and Achievements they have unlocked. At the top of their sheet, students could clearly see their Level, Title, XP earned, and the amount of XP required until they reach the next level. Each sheet was updated weekly, and students were encouraged to contact the instructors if they noticed any discrepancies. This provided them with weekly tracking of their progress in the class, and because they knew the total number of XP or points available, they could easily see where they were, percentage wise.

A bulletin board in the laboratory was used as a leader board. The board displayed each Guild's current normalized Rep, the distribution of Titles of each student in the Guild, the number of Quests each Guild had completed, and the Emblems each Guild had earned. The leader board was also updated throughout the semester on a weekly basis, and a condensed version was available on the course website.

4. Assessment

Student attitudes were assessed via anecdotal evidence and pre- and post-surveys were administered using Survey Monkey. The pre-survey was administered after the game was introduced to students but before the students had begun their first experiment of the semester. This survey was primarily designed to poll students about their attitude towards games in general (including video games, board games, and casual/social games) as well as their initial impressions about the game aspects of the class. After students had conducted all three of their experiments, they were given the post-survey, which asked how students felt about the same game aspects of the class, as well as how much they felt they participated in the game and whether or not we should run the game in the second semester of the laboratory course.

Student participation in the game was monitored by keeping track of the number of optional tasks each student completed in addition to their performance in the class. While a traditional experimental method with a control group was not employed, the content of the course (the style of the required reports, pre-labs, auto-ratings, etc.) is essentially identical to the 2011-2012 academic year. This group of students can be compared to the current group, as all that differed about the course was the way the content was delivered.

5. Mid-Year Evaluation

Fifty-one seniors took the gamified laboratory course in the Fall 2012 semester. All students were given the option to participate in the game aspects of the course, and each student did, to varying extents that will be discussed below. Forty-four of the fifty-one students completed the pre-semester survey, and fifty students completed the post-semester survey.

5.1 Student Attitudes Toward Games

When asked about their real-life gaming habits, expecting this to be a predictor to their readiness to embrace the game, it became apparent that the male students on average spent much more time playing video games than the female students. However, only three of the female students said they did not play any forms of video games, while the rest had been exposed to the medium via casual or social games. While we were concerned we may be alienating our female students, Figure 2 shows that none of the surveyed students indicated that they would not participate in the game at all.
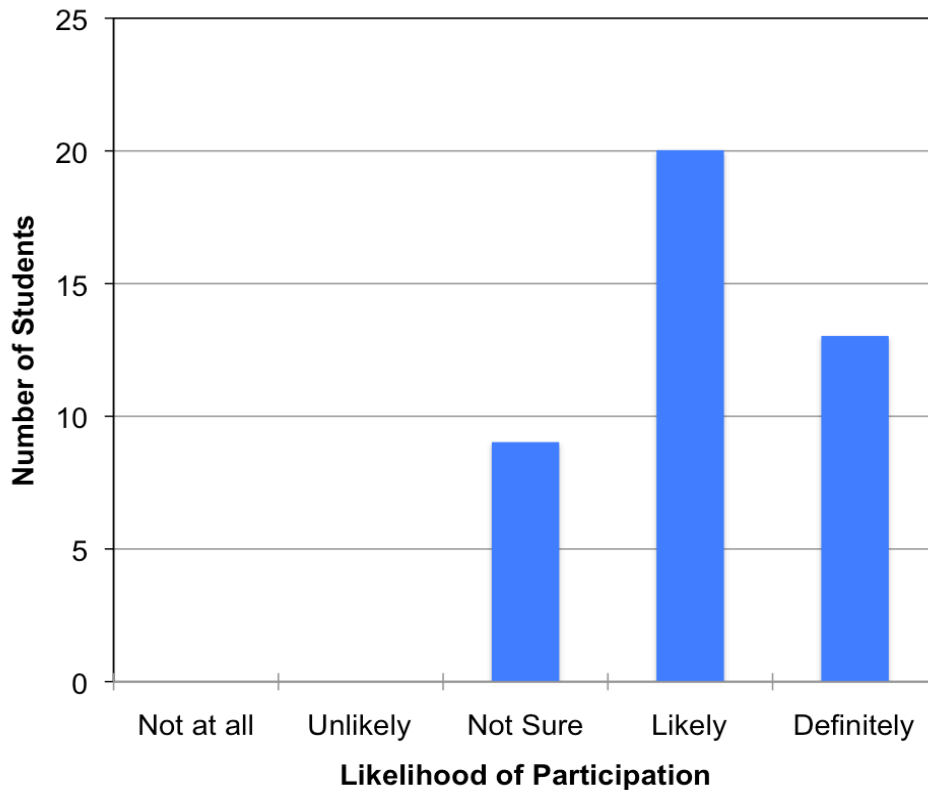
Figure 2. Student likelihood of participation in the optional game aspects of the course, based on the pre-experimental survey.

5.2 Student Opinion of Incentivized Tasks

Student participation in the optional tasks (the five Quests and the peer editing) can be seen in Figure 3, which shows the average participation of students based on their grades on the required course materials, which were the pre-labs, reports, and auto-ratings. While participation in the optional tasks tended to drop with student performance (i.e. high-performing students were the most likely to perform optional tasks), most students participated in at least one optional task per experiment. It is also interesting to note that performance in previous classes does not necessarily predict willingness to participate in the game. Three of the seven students who performed at least 9 optional tasks had a 3.0 or lower grade-point average. This suggested that the game aspects of the course were not just catering to students who would do every task presented to them. Furthermore, the game aspects did not just appeal to the top of the class, as less-high-achieving students were able to join the game and become engaged by the class.
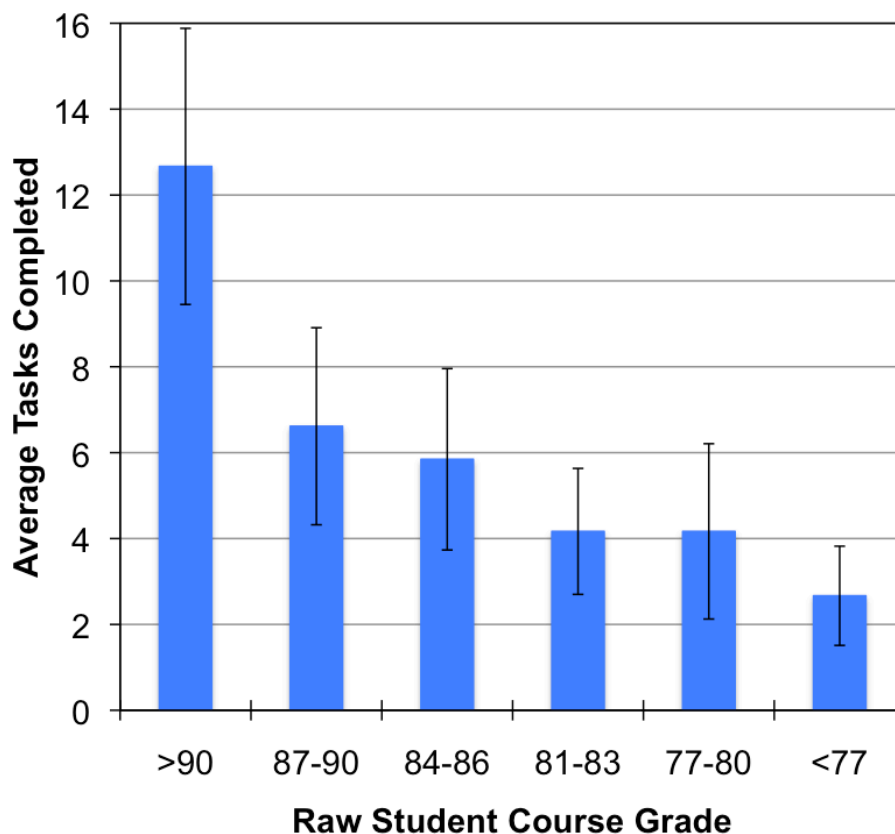
Figure 3. Average student participation in optional tasks, sorted by raw course grade. Three students scored above a 90, twelve students scored between 87 and 90, thirteen students scored between 84 and 86, twelve students scored between 81 and 83, six students scored between 77 and 80, and three students scored less than 77.

Participation in the Quests (the optional tasks repeatable once per lab report) decreased as the semester progressed. During the first experiment, students in the class completed 111 Quests. This number decreased to 71 Quests during the second experiment and 52 Quests during the final experiment. This drop-off was slightly anticipated, as students tended to become busier with other courses as the semester progressed. Furthermore, while doing each of the five available Quests was incentivized with XP, continued completion of the Quests after that was not incentivized, potentially contributing to the drop-off in participation. Many students expressed interest in doing the tasks as a means of boosting their grade during the pre-survey; however, they may not have realized the majority of the extra tasks awarded Rep at that time. Additionally, certain tasks, such having a report critiqued at the Writing Center, were only valid for the written report. This circumstance may have dissuaded some students from pursuing Quests later in the semester if they missed completing ones only available at certain times.

Student participation in each optional task (the five Quests and two Achievements related to peer editing) is displayed in Figure 4. Students seemed to favor the tasks that rewarded them for presenting data to instructors during and after their experiment was complete. Students tended to

feel that this task was useful and relatively easy to complete. It is interesting to contrast this attitude with students from last year, as there was virtually no attempt to perform these additional tasks when they were not incentivized via the game. Therefore, the extra incentive of Reputation appeared to motivate students to perform these additional tasks. It is also interesting to note the high participation numbers for peer editing of the written report draft. Like the Writing Center Quest, these Achievements only applied to the single written report of the semester. However, the two peer editing tasks each had greater participation than the external literature tasks, which could be performed for each experiment. This trend is likely caused by students' ability to earn XP for the peer review tasks, meaning they could boost their grade more directly. Throughout the semester, perhaps unsurprisingly, students seemed to favor tasks that would generate XP.
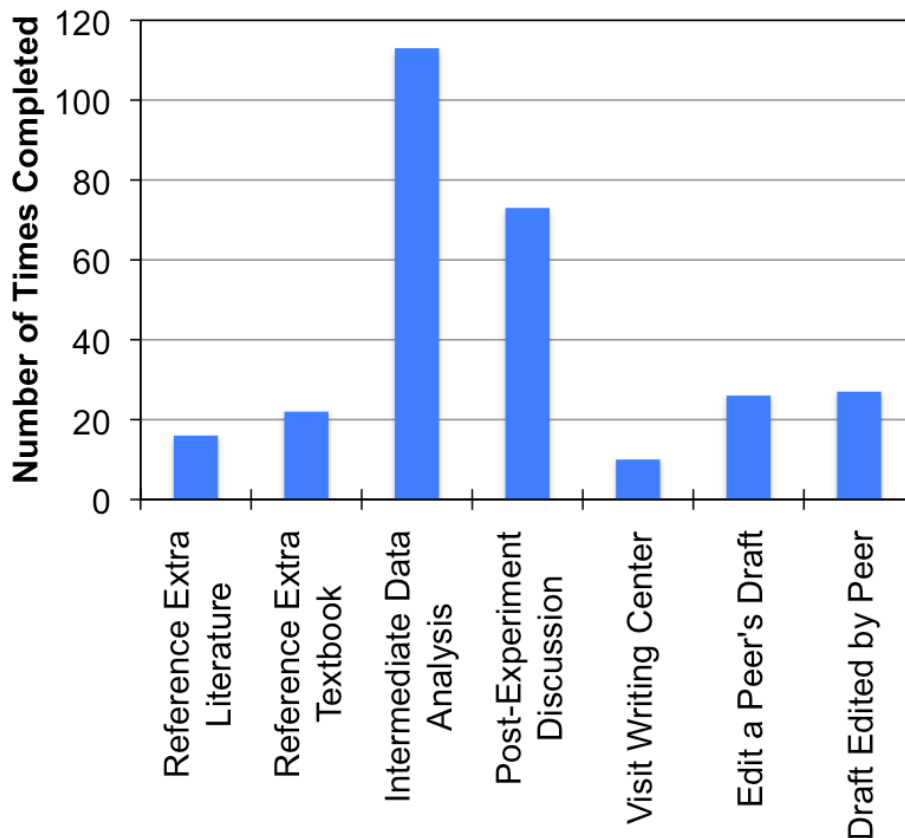

Figure 4. Number of times students completed specific optional tasks.

To attempt a quantitative comparison of student performance, the Fall 2011 semester was used as a point of comparison for this class, as the game was not implemented during that semester. The students' grades on their first written lab reports were compared. Although the precise grading method had changed, in both semesters, students were awarded 30 points for their analysis and 30 points for their communication abilities. In Fall 2011, students scored an average of 45 ± 7 out of the 60 available points. In Fall 2012, with the game implemented, students scored 46 ± 6 of the available 60 points. While a student t-test showed that the two groups did not show any statistically significant difference in scores, it should be noted that it is a relatively small sample size (only one offering of each mode of the class was available for comparison), and it can be difficult to control for variations in student performance and preparation in different class years.

Moving forward, it is hoped to be able to improve the quantitative assessment of learning differences, as the lab class will be offered twice per academic year, with different sets of students from the same cohort. This will essentially allow an 'experimental' and a 'control' group each year. This will be implemented in the fall 2013 semester.

While there is no difference between grades, student attitudes toward the class during the Fall 2012 semester seemed to have improved. Aside from participation in the individual tasks, many students embraced the team aspects of the game. Students in each Guild created Guild Facebook pages where the students could coordinate Title choice and share data for their Guild's major experiment. Numerous students made an effort to wear clothing in their Guild's color during the end-of-semester poster session, which only earned a minimal amount of Rep.

Moreover, the students who experienced the game seemed to have a much more positive attitude towards the course than students in prior years. Previously, some students were very vocal about their frustration with the laboratory course, either disliking experiments they were assigned, worrying that the grading was too harsh, or just writing off the laboratory as something they had to endure until graduation. While this may speak more to the personalities of the current group of students, anecdotally student complaints about the course were lower than expected.

5.3 Student Attitudes Toward Gamified Course

At the end of the semester, students were asked to evaluate similar questions to those they took on the pre-semester survey, as well as evaluate how much they felt they participated in the game, how much value they felt they gained from the optional tasks, and whether or not we should run the laboratory as a game next semester. Fifty students out of fifty-one responded to the survey.

According to the survey results, students felt they participated about as much as their classmates and about as much as they expected to in the beginning of the semester. Student responses seemed to skew slightly less than they expected with respect to their thoughts at the beginning of the semester, however. Some students indicated that they only wanted to do extra tasks that would help with the preparation of their lab reports and would not go out of their way to complete the others. Others expressed that some of the class was only interested in the tasks that would gain XP. Still other students said they became busier as the semester went on and simply did not have time to complete the amount of extra tasks they had expected to. The students that said they participated more than they expected said they found the extra tasks to be useful in preparing their reports and getting them to think about the experiments.

Next, students were asked to consider the aspects of the game they liked and did not like. Shown in Figure 5, students liked the overall idea of adding games to a class, the cooperative elements, the structure of rewards for work, and the incentivized tasks. These opinions mirrored the results of the pre-survey, in which most students indicated they at least somewhat liked the idea of these elements. Many students enjoyed being rewarded for performing actions they felt would strengthen their lab reports. One student noted that she felt motivated to participate in more optional tasks as to not let her Guild down, indicating the cooperative elements in this case can be used well as a motivational tactic. A few students disliked the cooperative nature of the class, citing that it was somewhat frustrating that some of their teammates were not participating in the

game, making it difficult for their Guild to win. This situation could be resolved, as one student suggested, by adding smaller XP rewards to more tasks.
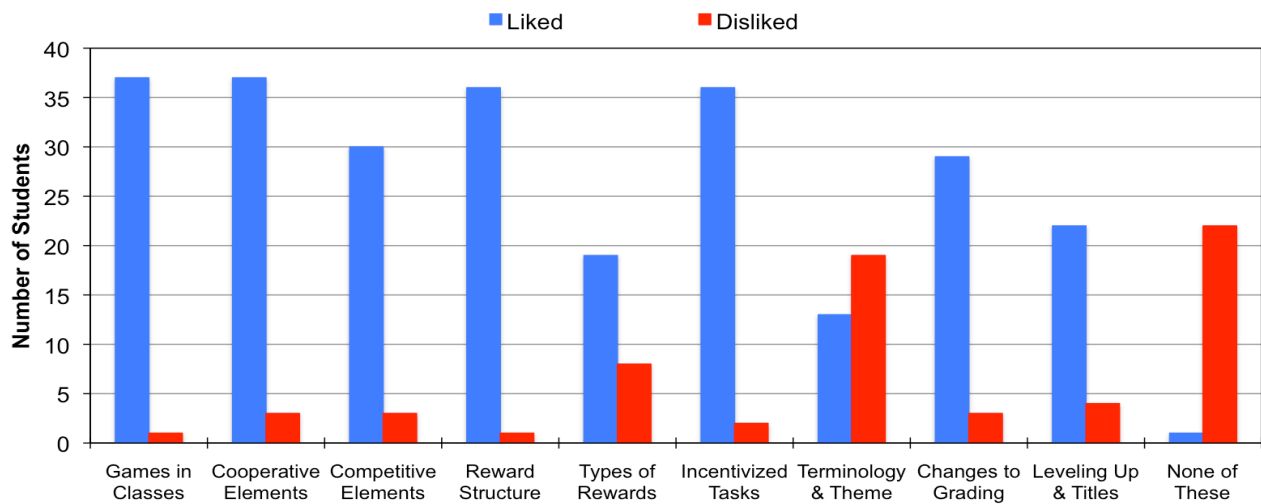

Figure 5. Student opinions of various aspects of the gamified course. These opinions were taken during the post-semester survey.

The only elements of the course that more than 10% of the students expressed a direct dislike for were the types of rewards available and the terminology and theme. These aspects also had the least number of students indicate that they liked them. This trend mirrored the results of the pre-survey, in which some students expressed confusion over the terminology and ambivalence toward the theme and rewards. Most students had indicated they slightly liked the rewards in the pre-survey, but most of the students felt neutral towards the theme. Students that disliked the rewards offered (points, pizza, or choice of experiment) felt that either the rewards were too balanced, so placing didn't matter, or that one reward (i.e. the extra XP) was worth much more than the other two. The theme and terminology failed to resonate with many of the students, as the students that indicated they didn't play video games felt somewhat lost. This situation was not the case for all students, as by the end of the first round of experiments many were using game terms correctly in conversation with one another, indicating they had a firm grasp of the game terminology. However, the overall attitude of the class toward that game seemed promising, as almost half of the students indicated they had no significant objections about the game as it was run this semester, citing the game's novelty and the change from a traditionally taught class.

When asked their opinions of the various tasks we incentivized, students felt that intermediate data analysis, discussing data with instructors, and peer editing were useful and valuable. Students on average felt neutral about the usefulness of searching for outside references and going to the writing center. The attitudes towards the writing tasks varied greatly from the seniors from the previous year. In the 2011-2012 academic year, we had required students to peer edit their drafts and had no incentive to get their drafts edited by the Writing Center. These students largely disliked peer editing and found it not very useful, and none of them brought their reports to the Writing Center.

Finally, students were asked their opinion of the game as it was run this semester. Figure 6 shows that the majority of the students enjoyed the game aspects of the class and that gender did not dictate student opinions of the game. When asked if the class should be run as a game again next semester, which is possibly the ultimate determination of the success or failure of this endeavor, the students were overwhelmingly positive. Of the 50 students that replied to the survey, 43 gave a definite yes to running the game, 6 students were ambivalent, and 1 student said a definite no. This suggests success in creating something that students found engaging and want to participate in again. In general, students found the game elements "refreshing" and made lab fun when it could have otherwise been seen as dry or boring. One student in particular felt that the game took away a perceived negative stigma attached to engineering laboratory courses. Some students indicated that they felt less anxious and stressed about grades and the class in general, as there were ample opportunities to "make up" for low report grades. Other students felt they had a sense of camaraderie with their Guilds, which they may not have had if the game aspect had not been introduced. Due to the anonymous nature of the initial survey, we could not match students who replied negatively to the final survey with those who might have indicated they were not gamers in the initial survey.
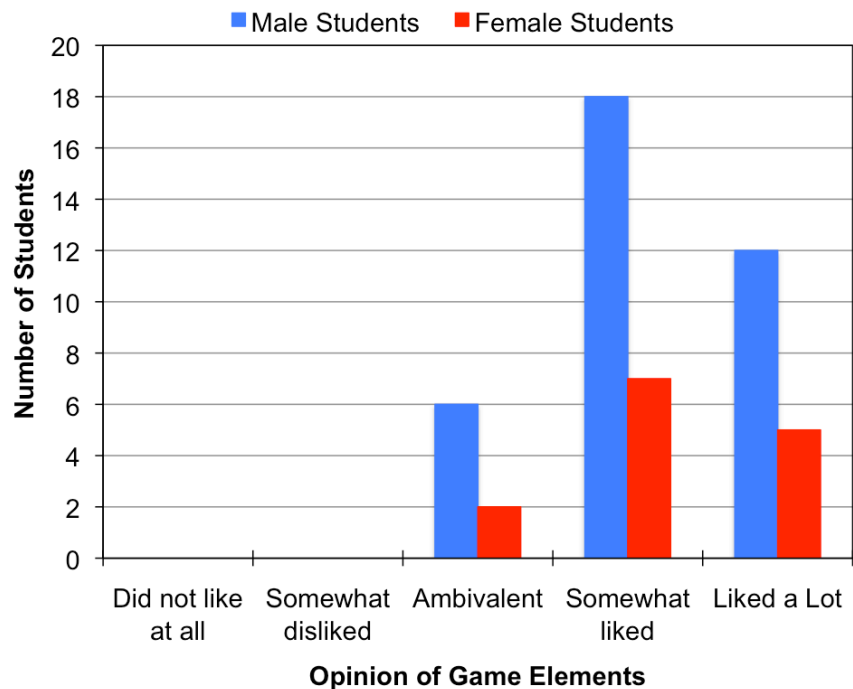

Figure 6. Student opinion of overall gamified course, displayed as the responses of male and female students.

6. Areas for Improvement:

A few areas were noted that could be improved for future offerings. The first major area that a large percentage (greater than 10%) of the students disliked was the use of the medieval fantasy theme and the terminology associated with it. While 28% of the 42 students that took the pre-semester survey indicated that they disliked or were confused by our terminology, 38% of the 50

students that took the post-semester survey indicated they did not like the themes and terminology. Students commented that they either had no attachment to the fantasy theme or were confused by the different terminology (such as the difference between a Quest and an Achievement). As such, at the end of the semester, we had the students vote for a theme for the following semester, with ideas ranging from the current theme to a popular property like Star Wars or Harry Potter to a Clue-style murder mystery. Allowing students to help design the game or have input into the theme of the construct may help broaden engagement and promote investment in the course. Additionally, students may be able to grasp the game more fully if they're dealing with terms that are familiar to them.

In addition, it was somewhat underestimated how much students valued XP. This trend was apparent when tabulating student votes for their rewards, which was the other major area that needs reevaluation. Of the six Guilds, four of them selected the lab report point boost as their most-desired reward, even eschewing the ability to select an experiment to perform in the spring semester, which the instructors considered as the most valuable reward of the three.   The instructors purposely tried to think of rewards that were more original than extra points, and the point boost reward was considered to be a consolation prize for the last-place group. As it turned out, one of the winning groups that selected the point boost did not benefit from them, as six of the eight students already had an A in the course. However, light was shed on this mentality in the post-semester survey, as one student commented the pizza was not viewed as a good prize because it was essentially "saving $6 on a meal" as opposed to something that would benefit them in the class (indeed, the pizza was selected last by all six of the groups). These will be considered when devising rewards for the spring semester, since pizza was unpopular and the selection of an experiment will not be an appropriate prize.

On the same note, while an effort was made to balance the Lab Titles in terms of overall Rep payout, students clearly valued XP more than Reputation. This trend can be seen in the fact that, while there were four different final Lab Title tracks to choose from, 43% of students elected to be Lab Healers, which was the only Title that could boost XP and not just Rep. The members of Guilds that had fallen into third place early on generally opted to become Lab Healers; many students in these positions felt that they weren't going to win the game, so they may as well try to maximize their XP total. This occurrence would appear to be a variation on the classic Prisoner's Dilemma from game theory, in which participants will often choose to maximize the benefits to themselves over possibly greater benefits achieved through cooperation. In the context of the class, this mentality was slightly disappointing, as there were ways for the teams to boost their Rep if they picked more diverse Titles or completed more optional tasks. However, as stated earlier, many students indicated in their post-semester surveys that they would have liked to participate more; they simply did not have the time. To remedy this imbalance, the Title and Ability system will be overhauled in the spring semester to try to further the concept of collaboration and cooperation.

To address the student complaint that some of the optional tasks (including the peer editing Achievements and the Writing Center Quest) were only valid for the one written report, and because the spring semester is focused more on group reports, these actions will no longer be Quests or Achievements. Instead, they will be replaced with tasks that incentivize students to keep the laboratory neat (which has traditionally been an issue) and to explore the broader

impacts of the technology they are experimenting with (which helps fulfill ABET criteria h and i). Rewards for peer editing and visiting the Writing Center will be converted to a Guild Emblem/Team Award if a certain amount of students complete it. It is expected that participation in these activities will decrease, but it is also desirable to leave some incentive there for students that wish to pursue it.

Finally, a tail-off in game participation was observed after the first experiment was completed. This trend was likely due to many students trying to earn the achievement for doing each of the five available Quests in the beginning, then stopping when they either achieved it or realized they could not go to the Writing Center for the final two presentation reports. In addition to restructuring the Quests as previously mentioned, students will unlock Extra Credit points depending on how many Quests they complete. For example, there are 18 possible Quests to complete during the spring semester. Students will earn 10 XP for every three Quests they complete. In this way, students who avoided Quests because they do not reward with XP will be motivated to complete them. In addition, students will be motivated to keep doing Quests throughout the semester.

Further improvements for the future include streamlining the method through which students' weekly progress reports are generated. It is time consuming to update fifty-one documents every week. A computer program may need to be developed in the future.

7. Conclusion

The game elements of the capstone chemical engineering laboratory course fulfilled most of the goals hoped for. Students became more interested and engaged in the course. Elements of the game that resonated with students the most included the team-based cooperative nature and the ability to earn extra points by performing tasks that, while they had not been traditionally quantified or graded in the past, benefit their understanding of the experiments. Many students stated that while they had fun with the game elements, they understood the value of the additional tasks they had the option to complete, which provided a useful learning experience. While it is difficult to discern if students learned the course material better in the presence of the game, it was clear that the game elements left a positive impression on students while motivating them to seek learning they may not have sought in the game's absence. While there are several improvements to be made that we feel could capture the interest of even more students, particularly the underperforming ones, the improved attitude of students toward the laboratory class was an encouraging sign that the first attempt at a game was an effective teaching tool.

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