MOTIVATING COMPUTER SCIENCE STUDENTS BEYOND CLASSWORK WITH GAMES AND GAMIFICATION

by

Stacey Watson

A dissertation submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
Computing & Information Systems

Charlotte

2018

Approved by:

Dr. Heather Lipford

Dr. Manuel Perez Quinones

Dr. Celine Latulipe

Dr. Florence Martin

ABSTRACT

STACEY WATSON. Motivating Computer Science Students Beyond Classwork with Games and Gamification. (Under the direction of DR. HEATHER LIPFORD)

Researchers have determined that games have the power to motivate users to engage for long periods of time with unparalleled intensity because they satisfy human psychological and emotional needs. In educational contexts, researchers have examined the effects of adding game and game elements and have found that they motivate students to put forth more effort in their coursework, something that is of particular interest to educators of the broad, complex and highly technical discipline of computer science.

By the time they graduate, computer science students need to have developed both technical expertise and proficiency in the non-technical skills of collaboration, communication skills and time management. However, it is challenging for students to gain sufficient technical and non-technical skills practice within the confines of a course or even a series of courses, and motivating students to engage outside of course requirements can be challenging.

In this dissertation, the data from three multiple-semesters studies, which ran in two large junior level computer science courses, reveal that games, gamification and game elements such as leaderboards and badges can, indeed, motivate students to go beyond course credit to practice both technical skills and essential non-technical skills to the computer science discipline.

ACKNOWLEDGMENTS

Firstly, I would like to thank my committee for their support and encouragement. Their dedication to furthering educational research has truly been an inspiration to me. In particular, I would like to express my sincere and heartfelt gratitude to my advisor, Heather Lipford, for her careful guidance and dedication and for challenging me in ways I could not have foreseen at the beginning of this journey.

I also would like to thank Harini Ramaprasad and Julio Bahamon for their willingness to risk implementing novel ideas in their classes. Our debates and discussions as we collaborated on our class have shaped me as an educator in many ways and I will be forever grateful to them.

Furthermore, I am deeply grateful for the guidance, support and encouragement of Mary Lou Maher and for her role in creating a nuturing environment in the department of Software and Information Systems at UNCC.

I extend a special thank you to my colleagues in the Center for Education Innovation. I treasured their comaraderie and unparalleled expertise in and enthusiasm for contemporary computer science pedagogy.

For their roles in igniting my passion for computer science educational research in the first place, I also express gratitude to Wayne Summers and Lydia Ray at Columbus State University, both of whom were instrumental in my decision to continue on to a doctorate after completing my master degee.

Finally, I thank my husband, Travis, for the significant sacrifices he made - I will be forever grateful for his willingness to uproot his life and put his career on hold

for my sake. Travis has been endlessly encouraging and supportive throughout our marriage, but really went above and beyond over the past six years. My profound love and gratitude go to him.

Glossary

Extrinsic motivation Motivation that occurs as a result of the promise of external rewards. For example, a person who pursues an activity because they hope to gain the benefit of an external outcome such as grades or money.

Flow A state of focused concentration and increased enjoyment whilst engaged in an interesting and challenging activity.

Gamification Game elements used in non-game contexts such as points, leaderboards, badges and so forth. In essence, gamification includes the game elements but lack other features of games such as goals or unifying themes. The impact of badges and leaderboards will be studied in this disseration.

Intrinsic motivation Motivation that occurs without any the promise of external rewards. For example, a person who pursues an activity because it is interesting and/or enjoyable in and of itself is said to be intrinsically motivated.

Serious games Unlike games which are designed to entertain, serious games are designed educate individuals within particular contexts using game mechanics and key game components such as goals, rules, challenges, and themes.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Research Motivations

Computer science is a broad, complex and highly technical discipline and, as such, there is limited time in an undergraduate program for students to learn both theory and skills. This is evident in the ACM/IEEE curricula in that that many of the learning outcomes expect students to be familiar with the concept (denoted in the curricula as "familiarity") and very few extend this theoretical knowledge to the point of developing hands-on skills (denoted as "usage" in the curricula) [32].

Graduates of computer science programs not only need to have developed technical expertise but they also need to have developed proficiency in non-technical skills. Communication is identified as a top skill for computer programmers, particularly as they are often called upon to convey highly technical subject matter to a non-technical or less familiar audience [17]. Additionally, collaboration is key as graduates will be expected to work constructively on technical teams [17]. Finally, time management is particularly important in IT-related careers as missed deliverable deadlines due to poor time management come at a high cost to both reputation and the bottom line. In fact, analysis by GamingWorks found that poor time management turned up as a cause for IT project failures in 9 of 13 research report lists generated by experts in the field [61].

However, it is challenging for computer science students to gain sufficient technical and non-technical skills practice within the confines of a course or even a series of courses. Gaining these skills often happens outside of class, through extra-curricular activities, internships, or just on students' own time. However, as modern students are working at an increasing rate and/or are juggling multiple roles [48], it is difficult to motivate students to spend additional time outside of course requirements for further skills practice. In this dissertation I investigate gamification as a means for motivating students to spend time honing these skills.

Researchers have noted that video games motivate users to engage with unparalleled levels of intensity for long periods of time [15]. This is largely attributed to the idea that games elicit powerful human emotions, including joy, frustration and curiosity [41]. Educators, seeking to tap into the powerful motivating effect of games, have found that using games and game elements in educational contexts can motivate students to put forth more effort [11] and can improve learning outcomes [4] as a result.

The main focus of educational games, however, should not be on the game itself, but rather should be about "incentivizing the right behavior that is aligned with the educational goals" [35]. In computer science, learning goals involve developing proficiency in programming languages and software tools as well as developing professional non-technical skills such as collaboration. In essence, a computer science student must learn how to use computers in innovative ways and how to collaboratively create tools. Developing these skills requires practice outside of class and this research demonstrates that games and gamification can provide the incentive.

1.2 Thesis Statement

Finding the time and space to develop computing skill abilities in the undergraduate computer science curriculum is a challenge, particularly as the discipline requires repetitive practice to master technical knowledge and skills. Furthermore, graduates of computer science programs are expected to have developed the professional non-technical skills of collaboration, communication and time management.

I hypothesize that games and gamification can motivate students to spend time outside of class to develop their non-technical and technical skills.

1.3 Games and Gamified Approaches

Research into games and gamification has shown that they can motivate students to engage more fully in their coursework [11] and can improve learning outcomes [4].

Games and game elements used in learning contexts can educate individuals within particular contexts using game mechanics and key game components such as goals, rules, challenges, and themes [33] [15].

Learning games can be found in many contexts such as the corporate world in the leadership and team management training video game *Pacific* [21]; as well as in heath care, such as in the first person health care simulation game for nurse trainees *Pulse!!* [20]. However, games are seen in abundance in educational contexts such as in the dragon-slaying Euclidean geometry game *Dragonbox Elements* for math students and in co-curricular competitions including spelling bees, academic decathlons, and for computer science students, hack-a-thons, robotics competitions, and capture the flag (CTF) competitions.

Some games bridge physical and virtual worlds such as Ceipidor et al.'s QR code museum treasure hunt game [5] and Zender et al.'s freshman orientation game in which students could earn virtual achievements for online and real-world tasks [62].

There have also been numerous examples of using game elements in computer science courses such the use of badges in a flipped CS1 class [38], the use of points, levels, leaderboards and badges in undergraduate and graduate computer organization courses [31], or even deriving student grades from experience points (XP) in a gamified cybersecurity module on incident response and investigation [53].

However, very little of game and gamification research explores whether these approaches would motivate students to go beyond course requirements. In general, co-curricular activities in computer science are limited to heavy-weight events such as hack-a-thons and capture-the-flag competitions, which typically require a great deal of skill mastery, time on the part of students and faculty, and funding for travel. As such, most students do not participate and, therefore, do not reap the benefits.

Miriovic and Peterson, seeking to expose more students to the educational benefits of capture-the-flag events, pulled these co-curricular serious games into their course requirements [44]. The problem with their approach is that it needs to be fit into the course curriculum and most faculty would be hard-pressed to find time in their courses for such activities. As such, a co-curricular approach that can reach more students than heavy-weight capture-the-flag and hack-a-thon events is desirable.

Ibanez et al., was one of the few studies to examine light-weight gamified co-curricular learning with badges. They found that 20 of 22 students continued working on tasks even after earning the maximum possible score in their C programming

class, with surveys indicating that many students were motivated by earning all of the badges [30]. My work extends this study by increasing the number of participants to over 600 and by assessing the effectiveness of games rather than only badges on motivating students to engage in co-curricular technical skill learning. Additionally, my work assesses the impact of game elements on student motivation to engage in the non-technical skills of collaboration, communication and time management.

1.4 Research Goals

This work addresses the primary research goal: how can games and gamification provide incentive for students to spend time outside of class to work on non-technical and technical skills? To address this goal, I investigate several game and gamification interventions. Consequently, this work concentrates on three main questions in addressing the primary research goal:

R1. Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?

R2. Which game elements (leaderboards and badges) provide incentive for students to go beyond the requirements for course credit to develop technical skills?

R3. Will gamification provide incentive for students to develop the non-technical skills of collaboration, communication and time management, which are essential to the discipline?

I address the above research questions in the following set of studies:

- Increasing Technical Skills Practice with a Hacker Game - This three-semester study uses a game where students learn and use BASH command-line skills to 'hack' the next password. This study was conducted on all sections of the undergraduate Introduction to Operating Systems and Networking class and addresses R1 and R2. See chapter 3.

- Increasing Programming Practice with a Serious Game - This two-semester study uses a game where students must write Ruby code to build enough artificial intelligence into their warrior to clear each level of a tower, rescuing captives and defeating enemies along the way. This game along with a leaderboard was inserted into the Software Engineering class right after the students learn Ruby basics and runs over the several weeks. This study addresses R1 and R2. See chapter 4.

- Improving Engagement in Non-Technical Skills - This two-semester study compares a gamified and a non-gamified approach to motivating students to engage in non-technical skills. The gamified approach uses Classcraft, a classroom behavior management game marketed for K-12 students. The tool was configured to promote collaboration, communication and time management skills in students and was integrated into all three sections of an undergraduate Introduction to Operating Systems and Networking class for the entire first semester of the study. In the second semester of the study, the game reward and penalty structure was replaced with participation points in the same undergraduate Introduction to Operating Systems and Networking class. This study addresses

R3. See chapters 5 and 6.

1.5 Organization and Contributions of This Work

Chapter 2 (Background) includes a literature review of the games and gamification research space.

Chapter 3 (Increasing Technical Skills Practice with a Hacker Game) describes a three-semester study that examined whether a hacker game would motivate students to engage in additional practice with BASH skills outside of course requirements. In this study, the main contribution is to demonstrate that a single game can, indeed, lead a non-trivial number of students to go beyond course requirements.

Chapter 4 (Increasing Programming Practice with a Serious Game) depicts a two-semester study that examined whether a serious game would motivate students to engage in additional Ruby programming practice beyond what was required for course credit. The contribution of this study is to demonstrate that a serious game can lead a non-trivial number of students to practice Ruby programming skills beyond what the course requires for credit when that game requires more effort than did the BASH game and when that game was extended over a number of weeks.

Chapter 5 (Improving Engagement in Non-Technical Skills with Gamification) details the first semester of a two-semester study that examined whether a gamified approach would motivate students to engage the non-technical skills of collaboration, communication and time management. In this semester of the study, in which I examined a gamified approach, I demonstrate that gamification does, indeed,

motivate students to communicate and to engage collaboratively with one another and does have a positive impact on time management for some students in terms of the number of missed assignments.

Chapter 6 (Improving Engagement in Non-Technical Skills with Participation Points) characterizes the second semester of a two-semester study that examined a gamified approach would motivate students to engage in the non-technical skills of collaboration, communication and time management. In this semester of the study, I examined a non-gamified participation point approach and then compared it to the gamified approach in chapter 5. I demonstrate that while the participation point approach is effective at incentivizing these non-technical skills over no intervention, gamification was more effective at incentivizing time management in the form of early submissions in the face-to-face classes and communication in the online classes. Additionally, I demonstrate that, with gamification, students collaborated in ways that were not possible with the participation points approach.

Chapter 7 (Conclusions and Future Work) presents a summary of my research contributions and discusses future work.

CHAPTER 2: BACKGROUND AND RELATED WORK

2.1 Games and Gamification

2.1.1 Serious Games

Serious games educate individuals within particular contexts using game mechanics and key game components such as goals, rules, challenges, and themes [33] [15]. In other words, these are games designed to be more than entertainment. Serious games are used in many educational contexts, including health care, K-12 and higher education, and corporate training.

Leadership and team management, for instance, are taught in the aforementioned serious video game Pacific [21], where players must use these skills to lead a fictional team off of an island after a plane crash. Pulse!! [20], a first person health care simulation game, provides case-based training to nurse trainees and DragonBox Elements [16] teaches math students basic Euclidean geometry and theorems while players build an army and work to defeat the evil dragon Osgard to save Euclids island.

Researchers have found that such games motivate their target audience and can lead to increased learning outcomes. In Buckley et al.'s [4] study, student learning outcomes were shown to increase as a result of a game where 156 online students bought and traded fictitious contracts and earned virtual money based on the accuracy of their forecasts.

Serious games have also been used in computer science education contexts, such as Robocode [49] in which players use Java programming skills to develop a robot tank to compete against tanks programmed by other players, and CoLoBoT [22], in which players use C, C++ or Java programming skills to colonize a planet. Muratet et al. [45] [46] developed a real-time strategy game, Prog&Play, to teach their students programming skills. Their results were promising. Their survey indicated that the students enjoyed the game campaigns and the serious game group performed better on the mid-term and final exams than the control group.

Additionally, competitive educational events such as spelling bees, academic decathlons, robotics competitions, hack-a-thons, and capture the flag (CTF) competitions also would fall into the serious games category. Typically, these competitive events are offered as a co-curricular experience rather than being incorporated into a particular course and require students to have prepared in advance for the competitions.

In fact, most competitive academic events require many weeks of preparation and take place over several days. This serves to limit the number of competitions that take place each year which, in turn, limits participation to those institutions with available travel funding and who have faculty with the time to train students outside of class time and to accompany student teams to the competitions.

Efforts have been made, however, to incorporate serious games into courses to allow more students the benefits of participation. For instance, Miriovic and Peterson propose smaller-scoped capture the flag competitions designed to be used in the classroom [44]. These exercises, like traditional capture the flag competitions, were

designed to engage participants in realistic, albeit simulated, attack and defense scenarios to teach them cybersecurity skills. However, they were offered multiple times per semester for entire classes of students and were lighter weight, were of shorter duration and were designed to require minimal investment of time on the part of faculty and students alike. Additionally, the Classroom Capture the Flag (CCTF) exercises were play-off based where student teams had numerous opportunities to learn from each encounter rather than being eliminated after only a single match. Finally, the exercises were designed to be more versatile than traditional CTFs in that they explored more than the usual gamut of exploiting vulnerabilities or protecting vulnerable systems and code from being exploited.

CTFs have been criticized for the ethical considerations of allowing students to play the role of the attacker. However, Miriovic and Peterson [44] argue that there are some very practical reasons for having students play both attacker and defender roles in that it equalizes the playing field such that both sides have a similar set of security background and skills. Furthermore, playing the role of attacker helps students develop the adversarial mindset necessary to adequately act as the defender. Nonetheless, the researchers added some safeguards to ensure that students did not abuse their developing offensive skills, such as requiring ethical training of every class that participates in the CCTFs, requiring students to play both the attacker and defender role and a required post-mortem analysis designed to emphasize the educational nature of the exercises.

Surveys with questions targeting skills and background knowledge were administered in an undergraduate Introduction to Security class at the University of Southern

California where the CCTFs were implemented. This allowed the instructor to divide the class into mixed level teams. Each exercise ran for two hours and were preceded by two to three weeks of lectures and hands-on exercises to teach the concepts and to introduce the skills required for the exercises. These concepts and skills were then applied during the CCTF exercise where researchers noted an increase in student interest. While there were mixed results in terms of how many teams completed the exercises, the researchers observed that students were able to apply the skills they learned in the lecture and hands-on exercises in the CCTF exercise even if they did not reach the end of the exercise. Furthermore, as students were graded on contribution rather than performance, they demonstrated a willingness to collaborate both within their team and with other teams. Finally, researchers noted that the CCTF exercises developed skills in scripting languages, network tools such as TCPDUMP and in Linux administration as well as skills in writing and testing network code - all important skills in cybersecurity [44].

While this approach certainly expands how many students can participate and scaffolds learning such that the exercises were a natural extension of the knowledge, skills and abilities taught in more traditional lectures and exercises, the CCTF exercises would require faculty to be knowledgeable and skilled in cybersecurity themselves. Nonetheless, these CCTFs certainly show that serious games could be powerful motivators for students to learn and practice computer science skills.

2.1.2 Pervasive Games

Pervasive games are an extension of serious games in that they bring "games into new contexts, situations and spaces" [15]. In essence, these games bridge physical and virtual worlds. The game intervention could be as simple as the use of QR codes with mobile devices, such as the museum treasure hunt devised by Ceipidor et al. [5], or as complex as full mobile apps with an accompanying web app, such as FreshUP, a game designed to help Freshman students orient themselves in their new university environment [62]. In FreshUP, students earn achievements in the form of virtual cards when they use their mobile phones or desktop computers to solve both online and real tasks and to communicate with other students.

This idea of bridging the physical and virtual realities was also present in Flushman et al.'s [18] alternative reality game, which taught computing concepts in a CS0 course through the lens of cybersecurity. Challenges were designed to differentiate learning such that it was both inclusive and supportive of students who had no background in computer science but also interesting and engaging to those who had some knowledge and/or experience in the area. Engagement was both promoted and maintained through a thematically connected story-line and the game play, which was designed to be cooperative, thus removing the isolation that students often feel in computing courses. Students were encouraged to explore a number of scenarios that could be easily translated to the real world both in terms of context and technical accuracy, thus addressing the social relevance barrier in the discipline. Student surveys indicated that students had changed their computing behaviors to be more secure and were

slightly more confident in their ability to learn both computer science and security.

The authors chose to use techniques drawn from alternate-reality games as research indicates that ARGs promote certain characteristics that are lacking in the computer science curriculum in general such as being "social and inclusive, stimulating counterfactual thinking, and supporting student autonomy" [18].

This project was different from the aforementioned competitive educational events in that students did not compete against one another and did not engage in attack/defense scenarios. Additionally the timeline extended over weeks rather than over a few hours or days and the learning was scaffolded and reinforced whereas most academic competitions are designed to be culminating experiences for students who have prepared in advance. The course did not assume that students had any computer science or cybersecurity knowledge at all and, in fact, aimed to teach the core computer science principles such that students would have both a foundation and context for more traditional introduction to computer science coursework. Additionally, the coursework and delivery mechanism were designed to remove common barriers to computer science engagement that have to do with student isolation, poor ties to social relevance and creative limitations.

Engagement was both promoted and maintained through the story-line and the game play, which was designed to be cooperative, thus removing the isolation that students often feel in computing courses. Students were encouraged to explore a number of scenarios that could be easily translated to the real world both in terms of context and technical accuracy, thus addressing the social relevance barrier in the discipline.

The main challenge with an alternate reality game that encourages students to explore adversarial thinking is that students may become confused between the game world and the real world. To avoid this issue, the course designers clearly delineated the game space to the students, which involved only attacking instructor-controlled systems. Furthermore, ethics, campus policies, responsible disclosure and State and Federal laws were frequently discussed in class. Again, as with the aforementioned CCTF serious game, the time and knowledge requirements for faculty to utilize this approach are extensive. Nonetheless, while the sample size was small and research needs to be done over a longer period of time, this approach seems to indicate that pervasive games could be powerful motivators for computer science students.

2.1.3 Gamification

Whereas the aforementioned serious games offer complete simulated environments and the alternate reality pervasive games offer a complete and unified story, gamification involves the use of the elements of game design in non-game contexts [15]. The difference lies in the word "elements". Gamified courses include elements of games but do not necessarily have any unifying theme that links these elements together into a comprehensive whole. These elements include such things as leaderboards, badges, achievements and other virtual rewards.

Leaderboards - scoreboards with the names and scores of the top competitors - are one of the most frequently used game elements in gamified courses. A study by Landers et al. [36], for instance, examined the effect of leaderboards on time-on-task in an online upper-division industrial/organizational psychology course. The

experiment compared time-on-task for two groups of students, one with a leaderboard and the other without, on a team wiki creation assignment. The gamified condition showed significantly greater time-on-task compared to the control condition.

These results were not atypical. In a systematic review of the impact of gamification on engagement in online programs, Looyestyn et al. [40] found that the majority of the research indicate that game elements such as leaderboards are effective interventions.

In fact, Landers et al. [36] was the only one in Looyestyn et al.'s review [40] that isolated a particular gamified intervention (leaderboards). The others used multiple game elements thereby confounding the results. As such, there needs to be more research done to isolate the effect of individual game elements.

Nonetheless, gamification as a whole has been shown to motivate students to engage more fully in their coursework, even beyond the basic requirements. Ibanez et al. [30], for example, developed a gamified learning platform called Q-Learning-G, where students were recognized through a leaderboard for their achievements of specific learning goals tied to work, planning and social activities in a C programming course. Students were required to earn at least 100 points in each activity area to demonstrate mastery of that area. Gamified elements included a leaderboard and badge and phase showcases where students' achievements were displayed. Results showed that many students continued working on the tasks even after earning the maximum possible score for the class and surveys indicated that many students were motivated by earning all of the badges.

Topîrceanu [57] implemented a fairly complex gamification solution whereby student grades were completely replaced with experience points (XP) and all instruc-

tional terms were replaced with game terms. Students became heroes, teams became guilds, assignments became quests and so forth. This study, conducted in undergraduate Algorithm Design and Analysis and Computer Organization classes with between 17 and 52 students revealed that the gamified classes had higher attendance, homework and quiz completion than the non-gamified classes.

In another example, Schreuders and Butterfield [53] used a design research methodology to produce a gamified cybersecurity module on incident response and investigation. Their aims were to cover the content while increasing student motivation and engagement and while fostering a positive learning experience for students. Topics included in the module were the management of information security and logs, intrusion detection, network and integrity monitoring and disk analysis. The main gamification involved deriving student grades from experience points (XP) earned by students for engaging in out of class activities related to the module learning outcomes and as they completed others tasks such as an independent study outside of class, lab activities, and reflective activities. An interactive virtual learning environment website was used to report on student experience points, which were divided into three types: skill XP, knowledge XP and wisdom XP. Students completed quests in each of these three categories to earn XP and, ultimately to "level up" their grade for the module. Students earned skill XP by completing applied labs and other learning tasks. Research, critiquing videos or readings, and completing multiple choice tests enabled students to earn knowledge XP. Finally, wisdom XP was earned by completing reflective tasks such as writing essays or completing attack trees. All three types of XP were weighted equally in the final grade calculation, however, there were many

more lab points available for skill XP than the other two categories.

Schreuders' and Butterfield's [53] results indicated that students felt that they spent more time on both in class and out of class tasks (quests) than in other modules of the course and that students felt that they learned more as a result. However, the statistical comparison on motivation conducted in the second year of the project was inconclusive in this regard. Students did, however, indicate that they preferred the gamified approach to the more traditional approach in the other course modules. As the gamified module only changed the way that the content was presented and graded, rather than the actual content, researchers concluded that their aim of content coverage was successful. Interestingly, the results indicated that the integrated game-like assessment activities in the module had less of an impact and were less compelling than the gamification of the module via the XP and quest system leading the researchers to suggest that the game elements such as XP and leaderboards can be effective with more traditional assessment activities.

However, a substantial increase in the grading workload in combination with the inconclusive findings when comparing student motivation with more traditionally taught course modules led researchers to conclude that the increased instructor workload did not justify continued gamification of the module in the way it was designed. Rather, they intend to explore ways to design gamified modules that are not as burdensome to the course instructors.

Dabrowski et al. [11] also implemented a teaching strategy that incorporated both the competitive aspects of serious games and gamified elements into a cybersecurity course. Unlike the above approach, however, the gamified environment was highly

automated via an auto-grader and therefore the course could accommodate over 400 students each year. One of the issues identified, however, was that the auto-grader was unable to assess partially completed challenges as it was designed not to force students to use a particular solution. This was meant to foster creativity as students could approach the problem in a number of ways and still come up with a valid solution.

The use of this automated system also provided instant feedback to students via a score board that displayed the student standings for each challenge as well as provided an overview of the latest challenges submitted, the students with the most submitted challenges, and the top scoring students in terms of the number of points earned. Students also earned extra points for being in the top five fastest to solve a challenge. These extra points were not incorporated into students grades, but nonetheless students were motivated by having the top scores.

Badges, ranks and course privileges were also provided as incentives, though the highest rank could only be achieved if students joined the capture the flag team for at least one competition. Hacker pseudonyms were randomly generated for all students, but the two highest ranks were permitted to choose their own hacker pseudonym, which in itself was a motivating factor for some students. Additionally, in an effort to make the game more engaging, the game challenges were wrapped in a story line modeled after the Hollywood hacking movie genre, which blurred the line between gamification and serious games.

Survey results indicated that students overwhelmingly found the competition and the use of scoreboards for providing feedback both motivational and enjoyable. Ad-

ditionally, the majority of students surveyed found the practical lab exercises useful and indicated that they would recommend the course to others. Furthermore, surveys indicated that students felt that the course increased their interest in the course topics and that they experienced a "strong knowledge gain" and that the knowledge gained would be "useful for their future" [11]. Finally, the bulk of the survey results indicated that students were either satisfied or very satisfied with the course.

The survey results led Dabrowski et al. [11] to conclude that a gamified and competitive approach was effective at motivating students to learn the course topics. However, it would have been useful had the researchers provided some demographics of their students, such as their gender, age, and cultural background. Additionally, some assessment of whether or not learning outcomes were being met would be necessary to truly assess the success of this project.

Nonetheless the research indicates that gamification can be effective at motivating students to engage with the course content, though more research needs to be done on learning outcomes. Also, as with serious and pervasive games, gamification can be a heavy burden for faculty to implement and maintain both in terms of time expenditure and necessary expertise in the subject matter [58][24].

2.2 Motivation

The primary use of serious games and gamification is to motivate students in educational contexts is to engage more deeply with the course content. Motivation research, according to Sailor et al. [52] broadly includes six perspectives that are relevant to games and gamification: trait, behaviorist learning, cognitive, self-determination,

interest and emotion. However, much of the game and gamification research on motivation has focused one main theoretical model: Self-Determination Theory (SDT), originally developed by Deci and Ryan [13].

According to SDT, human behavior is determined by the interplay of three basic psychological needs:

1. Autonomy - the need to self-organize experience and behavior for oneself
2. Competence - the need for challenge and to feel effective
3. Relatedness - the need to experience connection to others

Ryan, Risby and Przybylski [51] found that these needs were satisfied as follows in games:

- Autonomy - players are in charge of their game experience and so can self-organize their experiences and behaviors
- Competence - players experience challenge and the feeling of effectiveness as they complete levels and achievements in games
- Relatedness - players can connect with other players

Additionally, the research by Ryan et al. [51] found that satisfying the above needs were good predictors of whether or not a participant would persist in playing the game.

The Self-Determination Theory's motivational mechanisms overlap, at least partly, with several other perspectives [52], including the other major theoretical model: Uses & Gratification theory. The Uses & Gratification perspective was originally repurposed for digital games from Katz [34] by Sherry and Lucas [54] and assumes that

people choose their media, including games, to satisfy specific needs. In this theory, there are seven motivations for playing games. Games provide:

1. Control - players can exert control over their character in the game context
2. Challenge - players can push themselves to attain higher levels of skill
3. Competition - players can compete against other players
4. Fantasy - players can engage in a variety of acts that would be difficult, impossible or high risk in real life
5. Interest - players can explore the game world and can gather information about it as they play
6. Diversion - players can play to take a break from the concerns of real life
7. Social Interaction - players can interact with other players

I will examine motivation in my studies from the perspectives of Self-Determination Theory and Uses & Gratification Theory as they are the foremost theories on motivation as it pertains to games.

2.2.1 Game Design Elements and Motivation

As mentioned, the effects of games and gamification on motivation and psychological needs satisfaction have been largely studied. Positive results have been found on the motivational affordances provided through gamification elements such as points, leaderboards, achievements/badges, levels, story/theme, clear goals, feedback, rewards, progress, and challenge [25].

The main design elements often present in games include: points, badges, leaderboards, performance graphs, meaningful stories, avatars, and teammates.

Sailor et al. [52] examined the effects of specific game design elements on motivational needs fulfillment in their online digital simulation study of 699 participants. The results of this study found that the game design element group that included badges, leaderboards and performance graphs stimulated the need satisfactions of competence and autonomy whereas the game design element group that included avatars, meaningful stories, and teammates stimulated the need satisfaction of social relatedness. The other need satisfaction studied - autonomy with regard to decision freedom - was not stimulated by either of the game design element groups studied [52].

2.2.2 Intrinsic versus Extrinsic Motivation

There have been questions and concerns raised concerning the impact of games on intrinsic versus extrinsic motivation. Intrinsic motivation occurs without any the promise of external rewards and, as such, an intrinsically motivated person would pursue an activity because it is inherently interesting or enjoyable to them. Extrinsic motivation, on the other hand, only occurs when there is the promise of external rewards and, as such, an extrinsically motivated person would pursue an activity in order to gain some benefit, such as grades or money.

For instance, in the study by Ibanez et al., for their gamified Q-Learning-G platform, results showed that students continued working on the tasks even after earning the maximum possible score for the class. Surveys indicated that most of the students did so either because they wanted to earn all of the badges or because they were motivated to continue learning and mastering the C programming language. However,

the authors admit they were unable to conclude whether the students did the extra work because they were intrinsically motivated, were extrinsically motivated by the game elements, or did it because of some "complex interplay of motivational states" [30].

Ryan and Deci [50], in their work on self-determination theory (SDT), provide a continuum from intrinsic to extrinsic motivation, where an intrinsically motivated person is someone who pursues an activity because it is interesting and/or enjoyable in and of itself and an extrinsically motivated person is someone who would only pursue an activity to gain the benefit of an external outcome such as grades or money.

Intrinsic motivation has been further differentiated into motivation to know, motivation toward accomplishment, and motivation to experience stimulation. When a student enjoys learning for the sake of learning they are exhibiting motivation to know. Students who are motivated by a sense of accomplishment when they have completed something difficult are exhibiting motivation toward accomplishment. Finally, a student who enjoys an activity because it elicits sensory stimulation exhibits motivation to stimulation [60].

Researchers have found that external outcomes and incentives actually decrease intrinsic motivation in a number of contexts, depending on whether they were "informational" or "controlling" [12]. Co-curricular activities lack the controlling external outcome of grades, but it will be important to ensure that potentially external elements such as leaderboards, points and levels are not perceived as controlling such that they harm the students' intrinsic motivation.

An extrinsically motivated person, on the other hand, would only pursue an activity

to gain the benefit of an external outcome such as grades or money [50]. Deci et al. [12] broadly divide extrinsic motivation into three types: regulation motivation is where individuals are motivated by rules or sanctions, introjected motivation is when individuals are motivated by avoiding guilt or enhancing ego and, finally, identification motivation is when a person is motivated because their identity is tied to externally proscribed behavior.

Deci et al. [12] found that external outcomes and incentives actually decreased intrinsic motivation in a number of contexts, depending on whether they were "informational" or "controlling". Hanus and Fox [28] conducted a study that measured student motivation for 80 students in two 16-week in-person course sections with the same curriculum and the same instructor. The study was a between-subjects design where one course was gamified with badges and a leaderboard and the other course did not have the gamified elements. They found that students in the gamified course showed less intrinsic motivation as measured by the intrinsic motivation inventory by Deci and Ryan [13].

A study by Mekler et al. [43] found in a non-controlling context of tagging images that leaderboards, points and levels neither increased nor decreased intrinsic motivation for the 295 online students in the study. Furthermore, the addition of these gamified elements increased performance gains significantly. However, as Forde [19] points out, the inconclusive results could be attributed to the fact that the study examined the effects of leaderboards, points and levels but failed to compare informational with controlling game mechanic conditions. As such, my study designs include optional game levels to remove controlling elements.

Other studies did not look at the change in motivation, but rather examined the effectiveness of games and gamification on students who were intrinsically or extrinsically motivated toward the course at the outset. For instance, in the aforementioned study by Buckley et al. [4], the 156 online students were identified as intrinsically or extrinsically motivated toward the course through a pre-intervention survey. The results of this study indicated that their gamified intervention was most effective with students who were intrinsically motivated toward the course as measured by the pre-intervention survey, and, in particular, with students who were driven by motivation to know or motivation toward stimulation.

The intervention was also effective on students who were extrinsically motivated toward the course by identification, presumably because this is the closest external motivation on the continuum to intrinsic motivation. However, on the whole, the results indicated that the intervention was effective to a greater degree on the students whose pre-intervention survey indicated that they were intrinsically motivated toward the course. This study did not address whether or not students' motivation changed but rather looked at how effective gamification was on each of the groups.

Mekler et al. [42] on the other hand, in an online study that examined how points, leaderboards and levels impacted motivation in a non-controlling annotation task, found that these game elements did not impact intrinsic motivation at all. However, their findings suggested that the increased performance compared to the control condition could be attributed to an increase in extrinsic motivation as a result of the addition of the game elements.

Motivation is also largely dependent upon context and individual factors [12], some-

thing not accounted for by Buckley et al.'s [4] study.

Deterding [14] aptly points out that playing a recreational video game is voluntary and carries no consequences. This is not true of a leaderboard that leads to cash bonuses in the workplace or other external rewards. For instance, within an educational context, grades and course performance can be seen as controlling factors.

Furthermore, in general, the research on motivation and gamification fails to take into account that motivation is complex. Individuals could be both intrinsically and extrinsically motivated simultaneously [19].

It is evident that the results are mixed insofar as how games and gamification impact student motivation over the course of time as there are so many confounding variables such as course delivery methods (online, in-person, blended and so forth); course content and curriculum and student attitudes; and preferences; just to name a few. Much more research needs to be done in this area to identify when, where, and for how long gamified interventions should be deployed. While I do look at whether or not games and gamification will motivate students to continue past the required levels in this dissertation, I do not address their impact on intrinsic versus extrinsic motivation.

2.3 Flow

Flow, according to Csikszentmihaly [10], is an optimal psychological state of concentrated focus on a task that is appropriately challenging to a person's level of skill. Csikszentmihaly found that flow states can not only result in higher level of personal and work satisfaction, but can also lead to deep learning.

In a study of 134 high school physics students who played a physics game on optics and undergraduate mechanical engineering students who played a game on engineering dynamics, Hamari et al. [26] examined perceived challenge and skills, the two main elements of flow, to determine whether they did, indeed, predict engagement and immersion which, in turn, are believed to predict perceived learning.

The perceptions expressed by students in a psychometric survey were analyzed using structural equation modeling (SEM) to investigate the impact of flow (challenge and skill), immersion, and engagement on learning outcomes.

Results in this study indicate that not only does engagement have a positive effect on learning outcomes, but challenge was found to have a particularly strong correlation to learning outcomes. While I will not address learning outcomes in my studies, this will become important as student comments will reveal that challenge was a motivational mechanism in play for a number of respondents.

2.4 Time Effect

The question of how long a game or gamification intervention should last is an extremely important consideration as studies have found that there is a time effect, with the positive effects of games and gamification decreasing over time, suggesting that gamified approaches are more effective in the short-term [40] [43]. More research is needed to determine whether a gamified approach can lead to sustained engagement for an entire semester and what the impact would be on multiple gamified courses that span beyond a single semester.

In fact, some researchers have indicated that the results may have more to do with

the "novelty effect" rather than the motivational affordance of games and gamification [40], however, removing gamification after it has been implemented has had a detrimental effect on the users [56] and so timing and duration are important considerations.

As this time effect can impact the effectiveness of a game or gamification intervention, I examine it the two studies that span multiple weeks. It will be shown that in one of these studies student participation does fall off over time and supports the research on the time effect. In the other, however, student participation actually grows for quite a few weeks before it begins to drop off.

2.5 Learning Outcomes

Learning outcomes are also an important consideration, though the difficulty in measuring them has led to the majority of the studies done on games and gamification in education to focus on motivation and engagement as leading indicators for learning outcomes.

However, Landers and Landers [36], in their study on the effect of leaderboards on time-on-task and academic performance, did examine learning outcomes directly in a semester-long wiki assignment. In this study, the authors sought to use gamification as a way to increase student achievement by increasing the amount of time students spent on the project throughout the course of the semester. Four performance dimensions were identified from the project rubric: formatting, content, visuals and citations. The authors blindly rated random wiki articles on each dimension on a scale from 1 to 10. The class was divided into a gamified condition and a non-gamified

(control) condition. The results indicated that for all four learning outcomes, time-on-task strongly and statistically significantly predicted better learning outcomes. Furthermore, as indicated earlier, the gamified condition showed significantly greater time-on-task compared to the control condition.

On the other hand, in the aforementioned study by Hanus and Fox [28], intrinsic motivation declined in a gamified course and students in the gamified class scored lower final exam scores. Authors did not compare learning outcomes over the semester, and so their conclusions that the introduction of game elements do not improve educational outcomes are not completely convincing. However, their work does suggest that this may be the case.

While I do not examine learning outcomes in specific in this dissertation, these studies do suggest that higher motivation leads to increased time-on-task, which is a leading indicator of learning outcomes.

2.6 Online Learning

Much of the aforementioned research assumed the traditional face-to-face delivery method, yet there has also been research done on online learning where games and gamification seem to have a positive impact on engagement. In an expansive survey of gamification and online learning, Looyestyn et al. [40] reviewed fifteen studies on the effect of gamification on engagement, as measured by time spent, volume of contributions and occasions visited to the software. Of these 15 studies, 12 studies found that gamified approaches had a significant positive impact on engagement in online programs across numerous contexts from marketing to health awareness to

education.

However, there has been little research done to compare the effects of a gaming intervention on engagement in online versus in-person classes. However, as two of my studies will be done in both online and face-to-face sections of the Introduction to Operating systems and Networking course, there will be an opportunity to examine and compare the impact of games and gamification on both face-to-face and online delivery methods.

2.7 Lessons Learned and Future Directions

Each of the gamified approaches discussed showed promise in terms of increasing student engagement in course topics. Given the potential for tapping into the intensity that games elicit [15], games and gamification certainly have the potential to inspire students to practice their skills more frequently and even to engage with the material with more depth than otherwise occurs in an undergraduate class.

Additionally, the motivational impact of gamified interventions should be examined to be sure that the game is not undermining the motivation of some students even while boosting it for others. The effects of changes in motivation on engagement and learning outcomes should also be studied.

Furthermore, not much work has been done to study the time effect and just how long any particular gamified intervention is effective at motivating students to engage in the course materials and how this time effect impacts student learning outcomes.

Finally, more work needs to be done to determine if games and gamified approaches provide incentives for students to go beyond the course requirements toward mastering

the course topics rather than only completing the course requirements. In my studies I will examine whether games and gamification can engage students such that they will spend more time outside of class mastering technical skills and developing the non-technical skills of collaboration, communication and time management.

CHAPTER 3: INCREASING TECHNICAL SKILLS PRACTICE WITH A HACKER GAME

Computer science curricula have so many learning outcomes that often instructors are hard-pressed to find enough time in a course for students to learn both the theory and the hands on skills necessary to truly become proficient. While a great deal of independent practice is necessary to develop technical skills, it is difficult to motivate students to engage in practice outside of what is required for course credit since, as mentioned earlier, modern students are working at an increasing rate and/or are juggling multiple roles [48]. As such, in this study, I investigate whether a serious game would provide incentive for students to practice basic BASH skills beyond what was required for course credit. "Basic" BASH skills would include using commands such as those required to list and view directories and files, determine file types, estimate file space usage, search for files, sort the contents of files and output the results, piping of one command's output into another command and so forth.

This chapter depicts a three semester study where I mainly concentrate on the first research question (see Section 1.4): "Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R1) However, additional questions in the semester one survey focused on the second research question: "Which game elements (leaderboards, badges etc.) provide incentive for students to go beyond the requirements for course credit to develop technical skills?"

(R2)

I ran the study over three semesters. The Spring 2017 semester of the study provided a baseline for student willingness to engage in additional practice even after they have satisfied requirements for course credit in both face-to-face and online classes. I also explored student perceptions of using serious games to learn basic BASH skills in an online survey. Additionally, some additional questions were asked in the survey about badges to try to address their effect on student engagement to go above and beyond course requirements.

In the Fall 2017 semester, I removed badges so as to eliminate any possible confounds and in the Spring 2018 semester, I gathered more detailed data through console logging so as to more deeply assess student engagement by capturing student attempts and time spent on each level of the game. As with the first semester of the study, I also explored student perceptions of using serious games to learn basic BASH skills through an online survey.

3.1 Setting

At the University of North Carolina at Charlotte, Bourne Again Shell (BASH) commands are needed for the networking topics in the Introduction to Operating Systems and Networking course. See Appendix G for course information. However, there is not much time to cover and practice these commands within class.

In past semesters, course instructors assigned some online tutorials on the topic, but students identified BASH as a topic they did not enjoy in their course evaluations and it was clear that students needed additional incentive to practice with BASH outside

of class time to become comfortable with it. Thus BASH seemed to be a useful skill to use with games.

The course itself is a large, multi-section class that is required of all Bachelor of Science in Computer Science students at the University of North Carolina at Charlotte. All three sections of the course completed the same course content and activities, available to students via in our Learning Management System (LMS), Canvas.

The same three instructors taught the course throughout the three semesters of the study. The online section, which was taught by me, was asynchronous and, as such, students mainly worked independently on the course materials. The other two sections of the course, which were taught by two other instructors, were offered in a face-to-face format. In two face-to-face sections, instructors used the active learning, flipped-class format where students were required to complete preparatory activities before class, such as watching videos and/or reading articles and the textbook. Class time was spent completing learning activities in light-weight teams [38].

3.2 Game

Student hacking competitions are popular with computer science students and researchers such as Miriovic and Peterson [44] have explored smaller-scoped capture the flag competitions to allow more students the opportunity to participate. I wanted to see if using a hacker-themed serious game could engage students in BASH practice beyond course requirements. I also wanted to examine whether badges would further motivate students to complete additional BASH practice, even though they would not earn course credit for doing so.

OverTheWire's Bandit game [47] is one of a number of hacker "war games" developed and maintained by a group of volunteers led by Steven Van Acker. The hacker theme is critical as it provides a story element for the game, turning it into a unified serious game.

The Bandit game was cited as an example of a game to incorporate into the PolyLab project [23], in which Giacobe and Kohler developed polymorphic homework and laboratory assignments for teaching cybersecurity. However, the NICE (National Initiative for Cyber Education) conference presentation focused on development of PolyLab and did not examine the game itself.

Game-play for Bandit involves logging on to a server with secure shell (SSH) and then using BASH commands to discover ("hack") the password for the next level. The player defeats the level if they discover the password and can successfully log in to the next level of the game. Only 10 of the 21 levels of the Bandit game were used for this study.

The levels of the game become progressively more difficult, beginning with level 1, which requires only the most basic BASH commands (see Table 1) and ending, for this study, with level 10, which requires students to pipe one or more complex commands (see Table 2).

Level 10 was the most challenging for the students, as indicated by one student in the Spring 2017 survey, who suggested that this level should be called "god mod".

See Figure 1 for a sample console session in the game. Notice that students are instructed that the password to the next level is stored in the only human-readable file in the given directory. In this example, the user types a BASH command to

Table 1: Level 1 Commands

Command	**Use**
ls	Lists directory contents
cd	Changes to a new directory
cat	Concatenates file contents to the screen
file	Determines a files type
du	Estimates file space usage
find	Searches for files in a directory hierarchy given the directory

Table 2: Level 10 Commands

Command	**Use**
ls	Lists directory contents
cd	Changes to a new directory
file	Determines a files type
strings | grep	Pipes printable characters to grep which will output lines that match a given pattern
cat | sort	Pipes file contents to sort and outputs the sorted output
base64	Base64 encode or decode a file or standard input to standard output

change into the directory, followed by a command to discover which file holds that password and the command to view this file.

Prompt:

In this level, you will seek the level 5 password. An agent has leaked that the password for the next level is stored in the only human-readable file in the **inhere** directory. **Tip:** if your terminal is messed up, try the "reset" command.

Sample Console Session:

```
bandit4@bandit:~$ ls
inhere
bandit4@bandit:~$ cd inhere
bandit4@bandit:~/inhere$ ls -la
total 48
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file00
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file01
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file02
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file03
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file04
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file05
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file06
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file07
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file08
-rw-r----- 1 bandit5 bandit4   33 Dec 28  2017 -file09
drwxr-xr-x 2 root    root    4096 Dec 28  2017 .
drwxr-xr-x 3 root    root    4096 Dec 28  2017 ..
bandit4@bandit:~/inhere$ file ./-file*
./-file00: data
./-file01: data
./-file02: data
./-file03: data
./-file04: data
./-file05: data
./-file06: data
./-file07: ASCII text
./-file08: data
./-file09: data
bandit4@bandit:~/inhere$ cat ./-file07
koReBOKuIDDepwhWk7jZC0RTdopnAYKh
bandit4@bandit:~/inhere$
```

Figure 1: Level 4 Example Session

The Bandit game is hosted on an external site, and, as such, I did not have access to the server logs to track student interactions. In the design section below, I will

discuss how I collected data despite this limitation.

A companion Canvas exercise provided detailed instructions for how to use secure shell to get onto the OverTheWire Bandit server and the questions include some hints about which BASH commands might be helpful as well as links and tips for pulling up the manual pages in Linux. Students earned course credit for successfully discovering the passwords for the first seven levels of the game. A clear division was included after the mandatory questions where students were instructed that they could stop at this point should they choose to do so. The final three questions were the "challenge levels" and were not worth course credit in order to remove the controlling outcome of grades.

3.3 Design

As students use a variety of personal computing devices to work on the course, I decided to leverage the Linux shell environment in Cloud9, an Integrated Development Environment (IDE) in the cloud [8]. Students were already familiar with the interface from earlier course activities and it could be used from any device: tablets as well as laptops, netbooks and Chromebooks.

Bandit was assigned as a weekly exercise by all three sections. I estimated that it would take students 45 minutes to complete the seven mandatory levels, which would fit into the class-time allotted for the exercise in the face-to-face sections. The optional puzzles were estimated to take an additional 30 minutes. Each question is a separate level of the game so students do not have to answer all of the questions in a single session and, in fact, the data revealed that some students revisited the exercise

over the course of one or more days to complete levels as time allowed.

I also wanted to examine the impact of badges and, as such, in the Spring 2017 semester, badges were awarded in the online section using the CanvaBadges plug-in for Canvas as follows: A BASH Hacker Novice badge for successfully completing the first seven levels, a BASH Hacker Apprentice badge for completing levels 8 and 9 and a BASH Hacker Adept for completing level 10. See Figure 2.

Figure 2: Badges

I had originally planned to include badges in one of the face-to-face sections in this semester, but the course instructor did not have time to configure their Canvas course to include them. As such, I was limited in my ability to examine the impact of badges. In Fall 2017 semester of the study, I did not include badges for the online section so I could reduce the number of confounds between the online and face-to-face sections and so I could compare the Spring 2017 online class with badges to the Fall 2017 online class without badges. My intention was to add badges in the Spring 2018 semester of the study. However, the CanvaBadges plug-in was no longer available and, as such, I was unable to implement the badges as planned.

As my intention was to see if students would be motivated to do more than was required for course credit, I collected data on how many levels students completed to determine how many students went beyond the required levels. Additionally, I looked at the total time that students spent on the exercise to see if those who did more

than the required levels would spend more time-on-task doing so.

As I did not have access to the server logs for the Bandit game, for the Spring 2017 and Fall 2017 semester of the studies, I collected completion data and estimated time data via the companion exercise in Canvas. Students entered the passwords into fill-in-the-blank quiz questions after the password was discovered and verified on the server. The limitation with this methodology was that students could enter some or all of the passwords into the Canvas exercise at the same time.

However, in the Spring 2018 semester, I incorporated a BASH script that would save console logs in Cloud9 with interactions with the OverTheWire Bandit servers, along with time stamps. This not only prevented students from obtaining the passwords from a classmate, but it also allowed me to collect additional data about student attempts per level and obtain more accurate estimates of time taken for each game level. A final question in Canvas was added to the original exercise where students uploaded these logs.

3.4 Procedures

Students were introduced to the "Command-Line Hacker" exercise during class for the face-to-face sections and in Canvas in the online section in week 9 of the course. The face-to-face sections began the exercise during class time, where students could work in light-weight teams to complete them. These students were then given additional time after class to complete the exercise and any optional levels. The exercise was open to the online students for seven days.

After the exercise deadline had passed for all sections, course instructors sent a

recruitment email in the Spring 2017 semester of the survey and posted a Canvas recruitment message for the Fall 2017 and Spring 2018 semesters for students to complete a brief online survey about the exercise. Students were required to consent to participate in the anonymous survey, which included some basic demographic questions as well as questions about computer, mobile and board game behaviors, level attained in the game, perceptions about the game and about how the game impacted the students' motivation to continue playing. Student comments were categorized into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54] in an effort to capture how the game motivated students.

The badge condition for Spring 2017 students were also asked about perceptions about the use of badges and how they impacted students' motivation to continue playing. See page 203 in the appendices for the survey.

Anonymous exercise analysis and log data were collected from Canvas for each of the three sections of the course in all three studies. Additional console log data were collected in the Spring 2018 semester of the study. The exercise analysis provided information about how many levels each student completed, the Canvas log data revealed an estimate of how much time students took to complete each level of the game. The console log data revealed the number of levels completed, the number of attempts to discover the password in each level and an estimate of the time to completion. My study methods and data collection were approved by the University of North Carolina at Charlotte's Institutional Review Board (IRB Number: 17-0025). See appendix H.

3.5 Spring 2017

3.5.1 Participants

Study participants were students in the three sections of the Spring 2017 course.

In this semester of the study, 171 computer science majors aged 19-50 ($\mu = 23.21$, $\sigma = 4.90$) completed some or all of the Command-Line Hacker game levels in the exercise. The age distribution is depicted in Table 3. Among the participants, 150 (87.7%) were male and 20 (11.7%) were female. The grade point average (GPA) of the participants ranged from 2.0 to 4.0 ($\mu = 3.2$, $\sigma = 0.50$). The race/ethnicity demographics of the participants are shown in Table 4.

Table 3: Spring 2017 Age Distribution

Age	**# Participants**	**% Participants**
18 - 24	130	76.0
25 - 34	35	20.5
35 - 44	4	2.3
45 - 54	2	1.2

Table 4: Spring 2017 Race/Ethnicity Demographics

Race/Ethnicity	**# Participants**	**% Participants**
African American	19	11.1%
American Indian	1	0.6%
Any 2 or More Races	13	7.6%
Asian or Pacific Islander	28	16.4%
Caucasian	81	47.4%
Hispanic	14	8.2%
International	3	1.8%
Not Specified	12	7.0%

With respect to game playing behaviors, of 58 survey respondents, 4 (6.9%) reported that they did not play recreational computer or mobile games, 15 (25.9%) reported that they played more than 0 but less than 3 hours per week, 24 (41.4%)

reported that they played 3 to 7 hours per week, and 13 (22.5%) reported that they played more than 7 hours per week. See Table 5. While I cannot know how representative these results are as the survey was anonymous and voluntary, they do show that students spend a number of hours each week playing games.

Table 5: Spring 2017 Game Playing Behaviors of Respondents

Hours/Week Playing	**# Participants**	**% Participants**
None	4	6.9%
Greater than 0 but less than 3	15	25.9%
Between 3 and 7	24	41.4%
Greater than 7	13	22.4%

3.5.2 Results

The primary measures for this semester of the study were the number of game levels completed by the students in each section over all, the number of times they took a break from the game and at what level, and completion times. In all, the results were promising in students did spend additional time completing more levels than were assigned for course credit, demonstrating that serious games can motivate students to go beyond course requirements.

3.5.2.1 Completion Rates

In the first face-to-face section (F2F1), of the 60 participants, 57 students (95.0%) completed at least all of the mandatory levels. Of these, 25 students (41.7%) completed one or more of the optional game levels, 24 students (40%) completed all of the optional game levels and 32 students (53.3%) completed only the mandatory game levels. See Table 6.

In the second face-to-face section (F2F2), of the 47 participants, 45 students

(95.7%) completed at least all of the mandatory levels. Of these, 15 students (31.9%) completed one or more of the optional game levels, 13 students (27.7%) completed all of the optional game levels, 30 students (63.8%) completed only the mandatory game levels. See Table 6.

In the online section (UOL), of the 64 participants, 62 students (96.9%) completed at least all of the mandatory levels. Of these, 57 students (89.1%) completed one or more of the optional game levels, 46 students (71.9%) completed all of the optional game levels, and 5 students (7.8%) completed only the mandatory game levels. See Table 6.

Thus, between 32% and 89% of students completed more than the required levels.

Table 6: Spring 2017 Participant Completion Rates

Levels Completed	**F2F1**	**F2F2**	**UOL**
Some Mandatory	3 (5.00%)	2 (4.26%)	2 (3.13%)
Only Mandatory	32 (53.33%)	30 (63.83%)	5 (7.81%)
One or More Optional	25 (41.67%)	15 (31.91%)	57 (89.06%)
All Optional	24 (40.00%)	13 (27.66%)	46 (71.88%)

3.5.2.2 Time Spent

The time spent on this exercise was estimated from the time stamps in the companion Canvas exercise log. As the deadline was several days to a week after the exercise opened, some students stepped away and returned to the exercise. In order to generate a more accurate time for such students, a threshold of 60 minutes was set, after which point the student was assumed to have stepped away. These times were replaced with the mean of that level for all students in that section.

Across all sections in this study, there was only a 5.51 minute increase in average

completion times between the students who completed one or more of the optional levels (41.91 minutes) and the students who completed only the mandatory levels (36.4 minutes). On average, students who completed all of the optional levels spent an average of 46.77 minutes in the game, only 10.37 more minutes than their counterparts who completed only the mandatory levels. See tables 7 and 8.

In the first face-to-face section (F2F1), the average total time students spent in the game if they completed only the mandatory levels was 39.81 minutes. If they completed one or more of the optional levels, students spent an average of 51.13 minutes and students who completed all of the optional levels spent an average of 50.16 minutes in the game. See tables 7 and 8.

In the second face-to-face section (F2F2), the average total time students spent in the game if they completed only the mandatory levels was 32.29 minutes. If they completed one or more of the optional levels, students spent an average of 37.06 minutes and students who completed all of the optional levels spent an average of 36.20 minutes in the game. See tables 7 and 8.

In the online section (UOL), the average total time students spent in the game if they completed only the mandatory levels was 37.01 minutes. If they completed one or more of the optional levels, students spent an average of 43.18 minutes and students who completed all of the optional levels spent an average of 44.40 minutes in the game. See tables 7 and 8.

Table 7: Spring 2017 Participant Mean Completion Times

Levels Completed	All Sections	F2F1	F2F2	UOL
Only Mandatory	36.4	39.81	32.29	37.01
One or More Optional	41.91	51.13	37.06	43.18
All Optional	46.77	50.16	36.2	44.4

Table 8: Spring 2017 Participant Median Completion Times

Levels Completed	All Sections	F2F1	F2F2	UOL
Only Mandatory	33.58	32.17	32.37	38.88
One or More Optional	41.26	50.62	41.12	41.4
All Optional	43.57	47.72	41.12	41.64

3.5.2.3 Times Stepped Away

As mentioned earlier, the deadline was several days to a week after the exercise opened. As such, a threshold of 60 minutes was set, after which point the student was assumed to have stepped away.

In the first face-to-face section (F2F1), of the 60 participants, 17 (28.3%) stepped away from the exercise at least one time and then returned to work on it. Fourteen stepped away once, 2 stepped away twice and 1 stepped away three times. See Table 9. Three of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 14 of the participants only went on to complete the mandatory game levels. All three of the participants who completed one or more of the optional levels and who stepped away did so after they completed the mandatory game levels. See Table 10.

In the second face-to-face section (F2F2), of the 47 participants, 17 (36.2%) stepped away from the exercise at least one time and then returned to work on it. Thirteen stepped away once, 3 stepped away twice and 1 stepped away three times. See Table 9.

Six of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 10 of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. One of the participants who completed one or more of the optional levels and who stepped away did so after they completed the mandatory game levels. The remaining 5 of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 10.

In the online section (UOL), of the 64 participants, 17 (26.6%) stepped away from the exercise at least one time and then returned to work on it. 13 stepped away once, 2 stepped away twice and 2 stepped away three times. See Table 9. Sixteen of the participants who stepped away continued on to complete at least some of the optional game levels, whereas none of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. Three of the participants who completed one or more of the optional levels and who stepped away did so after they completed the mandatory game levels. The remaining 13 of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 10.

Across all sections in this semester, of the 171 participants, 51 (29.8%) stepped away from the exercise at least one time and then returned to work on it. Forty stepped away once, 7 stepped away twice and 4 stepped away three times. See Table 9. Twenty-five of the participants who stepped away continued on to complete

at least some of the optional game levels, whereas 25 of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. Four of the participants who completed one or more of the optional levels and who stepped away did so after they completed the mandatory game levels. The remaining 21 of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 10.

In essence, it is the promise of some course credit that draws students who have stepped away back into the game and some of these students do go on to complete more optional levels. Without this hook back to course credit, students are less likely to return to the game.

Table 9: Spring 2017 Number of Participants Who Stepped Away by Number of Times

# Times	All Sections	F2F1	F2F2	UOL
0	120	43	30	47
1	40	14	13	13
2	7	2	3	2
3	4	1	1	2

Table 10: Spring 2017 Number of Participants Who Stepped Away By Level Completed

Levels Completed	All Sections	F2F1	F2F2	UOL
Some Mandatory	2	0	1	1
Only Mandatory	24	14	10	0
One or More Optional	25	3	6	16
All Optional	19	3	4	12

3.5.3 Discussion

The Command-Line Hacker game did successfully motivate between 31.91% and 89.06% of students in the Spring 2017 semester to complete not only the mandatory levels but also one or more of the optional levels. The badges could have accounted for some of the significantly higher completion rates in the online section. However, the delivery method itself introduced too many confounds to come to any conclusions. The online students had all week to complete the exercise and could, conceivably, set aside a longer chunk of uninterrupted time to work on the exercise, unlike the face-to-face sections, which started the activity during class time.

In fact, 74.2% of the students who went beyond the mandatory levels finished the exercise in a single sitting compared with 64.9% of the students who did not go on to do any optional levels. This suggests that the students who did one or more optional levels may have been slightly more engaged in the exercise or found it easier and/or had prior experience with BASH commands. However, the students who completed one or more of the optional levels spent only an average of 10.37 minutes additional minutes in the game despite the fact that the optional levels were far more difficult than the mandatory levels (see tables 1 and 2). This suggests that students who went beyond the mandatory levels may have been slightly quicker than their counterparts who only completed the mandatory levels.

As for the survey results, I will address all three semesters at once and instead will now move on to discuss the Fall 2017 study.

3.6 Fall 2017

In the Fall 2017 semester of the study, I removed badges to try to ascertain the impact badges had on the online section and to provide a better comparison between the face-to-face sections and the online section.

3.6.1 Participants

In this semester of the study, 207 computer science majors aged 18-44 ($\mu = 22.19$, $\sigma = 3.6$) completed some or all of the Command-Line Hacker game levels in the exercise. The age distribution is depicted in Table 11. Among the participants, 176 (85.0%) were male and 26 (12.6%) were female. The grade point average (GPA) of the participants ranged from 1.92 to 4.0 ($\mu = 3.17$, $\sigma = 0.48$). The race/ethnicity demographics of the participants are shown in Table 12.

Table 11: Fall 2017 Age Distribution

Age	**# Participants**	**% Participants**
18 - 24	173	83.6%
25 - 34	27	13.0%
35 - 44	3	1.4%
Not Specified	4	1.9%

Table 12: Fall 2017 Race/Ethnicity Demographics

Race/Ethnicity	**# Participants**	**% Participants**
African American	20	9.7%
Any 2 or More Races	13	6.3%
Asian or Pacific Islander	26	12.6%
Caucasian	106	51.2%
Hispanic	11	5.3%
International	8	3.9%
Not Specified	23	11.1%

With respect to game playing behaviors, of 56 survey respondents, 10 (17.86%)

reported that they did not play recreational computer or mobile games, 19 (33.93%) reported that they played more than 0 but less than 3 hours per week, 9 (16.07%) reported that they played 3 to 7 hours per week, and 17 (30.36%) reported that they played more than 7 hours per week. See Table 13. Again, as with the previous semester, the survey revealed that students spend a non-trivial number of hours each week playing digital games.

In this semester of the study, I added a question which asked how much time students spent playing board games. Notice that these survey respondents spent far less time playing board games each week than digital games, with 36 (64.29%) reporting that they did not play them, 16 (28.57%) reporting that they played more than 0 but less than 3 hours per week, 3 (5.36%) reporting that they played 3 to 7 hours per week, and 0 (0.0%) reporting that they played more than 7 hours per week. See Table 13.

Table 13: Fall 2017 Game Playing Behaviors of Respondents

Hours / Week Playing	**# Participants**	
	Digital Games	**Board Games**
None	10 (17.86%)	36 (64.29%)
More than 0 but less than 3	19 (33.93%)	16 (28.57%)
3 to 7	9 (16.07%)	3 (5.36%)
Greater than 7	17 (30.36%)	0 (0.0%)

3.6.2 Results

The primary measures for this semester of the study were the number of game levels completed by the students in each section over all, the number of times they took a break from the game and at what level, and completion times. As in the Spring 2017 semester of the study, the results were promising in that students did spend additional

time completing more levels than what was assigned for course credit, demonstrating that serious games can motivate students to go beyond course requirements.

3.6.2.1 Completion Rates

In the first face-to-face section (F2F1), of the 90 participants, 87 students (96.7%) completed at least all of the mandatory levels. Of these, 37 students (41.1%) completed one or more of the optional game levels, 33 students (36.7%) completed all of the optional game levels and 50 students (55.6%) completed only the mandatory game levels. See Table 14.

In the second face-to-face section (F2F2), of the 43 participants, 40 students (93.0%) completed at least all of the mandatory levels. Of these, 15 students (34.9%) completed one or more of the optional game levels, 13 students (30.2%) completed all of the optional game levels, 25 students (58.1%) completed only the mandatory game levels. See Table 14.

In the online section (UOL), of the 74 participants, 72 students (97.3%) completed at least all of the mandatory levels. Of these, 24 students (32.4%) completed one or more of the optional game levels, 19 students (25.7%) completed all of the optional game levels, and 48 students (64.9%) completed only the mandatory game levels. See Table 14. Notice that the completion rates for all three sections, including those for the online section, are in line with those observed in the two face-to-face sections of the Spring 2017 study at between 31% and 41%.

Table 14: Fall 2017 Participant Completion Rates

Levels Completed	F2F1	F2F2	UOL
Some Mandatory	3 (3.33%)	3 (6.98%)	2 (2.70%)
Only Mandatory	50 (55.56%)	25 (58.14%)	48 (64.86%)
One or More Optional	37 (41.11%)	15 (34.88%)	24 (32.43%)
All Optional	33 (36.67%)	13 (30.23%)	19 (25.68%)

3.6.2.2 Time Spent

Just as in the Spring 2017 semester of the study, the time spent on this exercise was estimated from the time stamps in the companion Canvas exercise log. As the deadline was several days to a week after the exercise opened, some students stepped away and returned to the exercise. In order to generate a more accurate time for such students, a threshold of 60 minutes was set, after which point the student was assumed to have stepped away. These times were replaced with the mean of that level for all students in that section.

Across all sections in this semester of the study, there was a 3.34 minute decrease in average completion times between the students who completed only the mandatory levels (38.81 minutes) and the students who completed one or more of the optional levels (35.47 minutes). Recall that there was a 5.51 minute increase in average completion times in the Spring 2017 semester for the students who completed one or more optional levels.

On average, students who completed all of the optional levels spent 35.44 minutes in the game, 3.37 fewer minutes than their counterparts who completed only the mandatory levels. See tables 15 and 16. Recall that students who completed all of the optional levels in the Spring 2017 semester spent 10.37 more minutes in the game

on average.

In the first face-to-face section (F2F1), the average total time students spent in the game if they completed only the mandatory levels was 35.39 minutes. If they completed one or more of the optional levels, students spent an average of 34.14 minutes and students who completed all of the optional levels spent an average of 31.06 minutes in the game. See tables 15 and 16.

In the second face-to-face section (F2F2), the average total time students spent in the game if they completed only the mandatory levels was 37.45 minutes. If they completed one or more of the optional levels, students spent an average of 36.16 minutes and students who completed all of the optional levels spent an average of 38.67 minutes in the game. See tables 15 and 16.

In the online section (UOL), the average total time students spent in the game if they completed only the mandatory levels was 43.40 minutes. If they completed one or more of the optional levels, students spent an average of 37.05 minutes and students who completed all of the optional levels spent an average of 40.67 minutes in the game. See tables 15 and 16.

Table 15: Fall 2017 Participant Mean Completion Times

Levels Completed	**All Sections**	**F2F1**	**F2F2**	**UOL**
Only Mandatory	38.81	35.39	37.45	43.4
One or More Optional	35.47	34.14	36.16	37.05
All Optional	35.44	31.06	38.67	40.67

3.6.2.3 Times Stepped Away

As mentioned earlier, the deadline was several days to a week after the exercise opened. As such, a threshold of 60 minutes was set, after which point the student

Table 16: Fall 2017 Participant Median Completion Times

Levels Completed	All Sections	F2F1	F2F2	UOL
Only Mandatory	36.63	32.85	35.94	42.33
One or More Optional	33.74	33.74	31.18	37.51
All Optional	33.83	31.07	36.67	42.42

was assumed to have stepped away.

In the first face-to-face section (F2F1), of the 90 participants, 25 (28.3%) stepped away from the exercise at least one time and then returned to work on it. Nineteen stepped away once and 6 stepped away twice. See Table 17. Thirteen of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 11 of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. All of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 18.

In the second face-to-face section (F2F2), of the 43 participants, 17 (39.5%) stepped away from the exercise at least one time and then returned to work on it. Fourteen stepped away once, 2 stepped away twice and 1 stepped away three times. See Table 17. Four of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 13 of the participants only went on to complete the mandatory game levels. All of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 18.

In the online section (UOL), of the 74 participants, 24 (32.4%) stepped away from

the exercise at least one time and then returned to work on it. Eighteen stepped away once, 5 stepped away twice and 1 stepped away three times. See Table 17. Four of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 19 of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. All of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 18.

Across all sections in this semester of the study, of the 207 participants, 66 (31.9%) stepped away from the exercise at least one time and then returned to work on it. Fifty-one stepped away once, 13 stepped away twice and 2 stepped away three times. See Table 17. Twenty-one of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 43 of the participants only went on to complete the mandatory game levels and 2 of the participants did not complete all of the mandatory game levels. All of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 18. Recall that in the Spring 2017 semester, only 4 of the 25 participants who stepped away and completed some of the optional levels, did so after they completed the mandatory game levels.

As mentioned earlier, it is the promise of some course credit that draws students who have stepped away back into the game and some of these students do go on to complete more optional levels. Without this hook back to course credit, students are less likely to return to the game.

Table 17: Fall 2017 Number of Participants Who Stepped Away by Number of Times

# Times	All Sections	F2F1	F2F2	UOL
0	141	65	26	50
1	51	19	14	18
2	13	6	2	5
3	2	0	1	1

Table 18: Fall 2017 Number of Participants Who Stepped Away By Level Completed

Levels Completed	All Sections	F2F1	F2F2	UOL
Some Mandatory	2	1	0	1
Only Mandatory	43	11	13	19
One or More Optional	21	13	4	4
All Optional	19	12	4	3

It should be noted here that there was a parallel study running in these classes at the same time (see Chapter 5), which could have confounded these results somewhat. However, as the results were consistent with those in the face-to-face sections of the Spring 2017 semester, it appears that the impact was negligible.

3.6.3 Discussion

The Command-Line Hacker game did successfully motivate between 32.43% and 41.11% of students in the Fall 2017 semester to complete not only the mandatory levels but also one or more of the optional levels. The online course without badges was no longer an outlier at 32.43%.

Additionally, 72.4% of the students who went beyond the mandatory levels finished the exercise in a single sitting compared with 65.6% of the students who did not go on to do any optional levels. This suggests that the students who did one or more optional levels may have been slightly more engaged in the exercise or found it easier and/or had prior experience with BASH commands. Furthermore, the fact the students

who stepped typically did so before they completed the mandatory level suggests that the 'hook' to course credit is what pulled them back. Once there, many went on to complete optional levels, perhaps because they had entered a state of focused concentration and increased enjoyment whilst engaged in an intrinsically interesting activity, otherwise characterized as a flow state [10].

Finally, the students who completed one or more of the optional levels spent an average of 3.34 **fewer minutes** in the game despite the fact that the optional levels were far more difficult than the mandatory levels (see tables 1 and 2). This suggests that students who went beyond the mandatory levels were quicker than their counterparts who only completed the mandatory levels.

3.7 Spring 2018

In the Spring 2018 semester of the study I added console logs of interactions in the game itself to gain more precise time data, given that it was possible that students could have collected the answers and submitted them to Canvas all or several at once.

3.7.1 Participants

In this semester of the study, 226 computer science majors aged 18-40 ($\mu = 22.05$, $\sigma = 3.32$) completed some or all of the Command-Line Hacker game levels in the study exercise. The age distribution is depicted in Table 19. Among the participants, 192 (85.0%) were male and 31 (13.7%) were female. The grade point average (GPA) of the participants ranged from 1.25 to 4 ($\mu = 3.25$, $\sigma = 0.52$). The race/ethnicity demographics of the participants are shown in Table 20.

With respect to game playing behaviors, of 147 survey respondents, 10 (6.8%)

Table 19: Spring 2018 Age Distribution

Age	# Participants	% Participants
18 - 24	185	81.9%
25 - 34	34	15.0%
35 - 44	4	1.8%
Not Specified	3	1.3%

Table 20: Spring 2018 Race/Ethnicity Demographics

Race/Ethnicity	# Participants	% Participants
African American	24	10.6%
Any 2 or More Races	13	5.8%
Asian or Pacific Islander	36	15.9%
Caucasian	126	55.8%
Hispanic	11	4.9%
International	8	3.5%
Not Specified	8	3.5%

reported that they did not play recreational computer or mobile games, 40 (27.21%) reported that they played more than 0 but less than 3 hours per week, 46 (31.29%) reported that they played 3 to 7 hours per week, and 44 (29.93%) reported that they played more than 7 hours per week. See Table 21. These survey respondents spent far less time playing board games each week, with 90 (61.22%) reporting that they did not play them, 36 (24.49%) reporting that they played more than 0 but less than 3 hours per week, 11 (7.48%) reporting that they played 3 to 7 hours per week, and 3 (2.04%) reporting that they played more than 7 hours per week. See Table 13. Again, however, as with the previous two semesters, the survey revealed that students spend a non-trivial number of hours each week playing games in general.

3.7.2 Results

The primary measures for this study were the number of game levels completed by the students in each section over all, the number of times they took a break from

Table 21: Spring 2018 Game Playing Behaviors of Respondents

Hours / Week Playing	**# Participants**	
	Digital Games	**Board Games**
None	10 (6.8%)	90 (61.22%)
More than 0 but less than 3	40 (27.21%)	36 (24.49%)
3 to 7	46 (31.29%)	11 (7.48%)
Greater than 7	44 (29.93%)	3 (2.04%)

the game and at what level, and completion times. As with both of the previous semesters, the results were promising in that students did spend additional time completing more levels than what was assigned for course credit, demonstrating that serious games can motivate students to go beyond course requirements.

3.7.2.1 Completion Rates

In the first face-to-face section (F2F1), of the 103 participants, 100 students (97.1%) completed at least all of the mandatory levels. Of these, 54 students (52.4%) completed one or more of the optional game levels, 46 students (44.7%) completed all of the optional game levels and 46 students (44.7%) completed only the mandatory game levels. See Table 22.

In the second face-to-face section (F2F2), of the 41 participants, 40 students (97.6%) completed at least all of the mandatory levels. Of these, 25 students (60.98%) completed one or more of the optional game levels, 15 students (36.59%) completed all of the optional game levels, 15 students (36.59%) completed only the mandatory game levels. See Table 22.

In the online section (UOL), of the 82 participants, 76 students (92.7%) completed at least all of the mandatory levels. Of these, 27 students (32.9%) completed one or more of the optional game levels, 22 students (26.83%) completed all of the optional

game levels, and 49 students (59.76%) completed only the mandatory game levels. See Table 22.

As with the previous semester, the online section fell firmly into the 31% to 41% observed for students who did one or more optional levels in the Fall 2017 semester and in the face-to-face sections of the Spring 2017 semester. The face-to-face sections were higher, at 52% and 61%.

Table 22: Spring 2018 Participant Completion Rates

Levels Completed	**F2F1**	**F2F2**	**UOL**
Some Mandatory	3 (2.9%)	1 (2.4%)	6 (7.3%)
Only Mandatory	46 (44.7%)	15 (36.59%)	49 (59.76%)
One or More Optional	54 (52.4%)	25 (60.98%)	27 (32.9%)
All Optional	46 (44.7%)	15 (36.59%)	22 (26.83%)

3.7.2.2 Time Spent

The time spent on this exercise was estimated from the time stamps in the console logs that students submitted as part of the Canvas companion exercise. As the deadline was several days to a week after the exercise opened, some students stepped away and returned to the exercise. In order to generate a more accurate time for such students, a threshold of 60 minutes was set, after which point the student was assumed to have stepped away. These times were replaced with the mean of that level for all students in that section.

Across all sections in this study, there was only a 4.44 minute increase in average completion times between the students who completed only the mandatory levels (37.17 minutes) and the students who completed one or more of the optional levels (41.61 minutes). Recall that there was a 5.51 minute increase in average completion

times in the Spring 2017 semester and a 3.34 minute decrease in average completion times in the Fall 2017 semester for the students who completed one or more optional levels.

On average, students who completed all of the optional levels spent an average of 39.91 minutes in the game, only 2.74 more minutes than their counterparts who completed only the mandatory levels. See tables 23 and 24. Recall that students who completed all of the optional levels in the Spring 2017 semester spent 10.37 more minutes in the game on average and in the Fall 2017 semester spent 3.37 fewer minutes in the game on average.

In the first face-to-face section (F2F1), the average total time students spent in the game if they completed only the mandatory levels was 39.07 minutes. If they completed one or more of the optional levels, students spent an average of 40.99 minutes and students who completed all of the optional levels spent an average of 39.79 minutes in the game. See tables 23 and 24.

In the second face-to-face section (F2F2), the average total time students spent in the game if they completed only the mandatory levels was 52.88 minutes. If they completed one or more of the optional levels, students spent an average of 50.20 minutes and students who completed all of the optional levels spent an average of 48.49 minutes in the game. See tables 23 and 24.

In the online section (UOL), the average total time students spent in the game if they completed only the mandatory levels was 30.70 minutes. If they completed one or more of the optional levels, students spent an average of 35.37 minutes and students who completed all of the optional levels spent an average of 34.21 minutes

in the game. See tables 23 and 24.

Table 23: Spring 2018 Participant Mean Completion Times

Levels Completed	All Sections	F2F1	F2F2	UOL
Only Mandatory	37.17	39.07	52.88	30.70
One or More Optional	41.61	40.99	50.20	35.37
All Optional	39.91	39.79	48.49	34.21

Table 24: Spring 2018 Participant Median Completion Times

Levels Completed	All Sections	F2F1	F2F2	UOL
Only Mandatory	33.38	33.96	47.40	28.26
One or More Optional	38.67	37.45	54.53	24.95
All Optional	36.83	36.98	45.13	23.79

When the mean time per level was calculated, there was only a slightly significant difference (p-value 0.0031) in the mean minutes per level. Students who completed only the mandatory levels did so with a mean time of 5.31 minutes per level and students who completed one or more of the optional levels did so with a mean time of 4.36 minutes per level. See Table 25.

3.7.2.3 Commands per Level

Students who completed only the mandatory levels did so in an average of 12.1 commands per level and students who completed one or more of the optional levels did so in an average of 10.5 commands per level. The students who completed all optional levels did so in an average of 9.7 attempts per level. See Table 25. While it seems that students who completed one or more optional levels were slightly more efficient than those who completed only the mandatory levels there was no statistically significant difference (p-value 0.027).

Table 25: Spring 2018 Mean Commands and Minutes per Level

Levels Completed	Mean Attempts/Lvl	Mean Min/Lvl
Only Mandatory Levels	12.1	5.3
One or More Optional Levels	10.5	4.36
All Optional Levels	7.24	3.99

3.7.2.4 Times Stepped Away

As mentioned earlier, the deadline was several days to a week after the exercise opened. As such, a threshold of 60 minutes was set, after which point the student was assumed to have stepped away.

In the first face-to-face section (F2F1), of the 103 participants, 13 (12.6%) stepped away from the exercise at least one time and then returned to work on it. All 13 stepped away only one time. See Table 26. Eight of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 4 of the participants only went on to complete the mandatory game levels and 1 of the participants did not complete all of the mandatory game levels. Six of 8 of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 27.

In the second face-to-face section (F2F2), of the 41 participants, 11 (36.8%) stepped away from the exercise at least one time and then returned to work on it. Eight stepped away once, 2 stepped away twice and 1 stepped away three times. See Table 26. Four of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 7 of the participants only went on to complete the mandatory game levels. Two of the 4 participants who completed

one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 27.

In the online section (UOL), of the 82 participants, 10 (12.19%) stepped away from the exercise at least one time and then returned to work on it. All 10 stepped away only one time. See Table 26. Three of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 5 of the participants only went on to complete the mandatory game levels and 2 of the participants did not complete all of the mandatory game levels. Two of 3 of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 27.

Across all sections in this study, of the 226 participants, 38 (16.8%) stepped away from the exercise at least one time and then returned to work on it. Thirty-one stepped away once, 2 stepped away twice and 1 stepped away three times. See Table 26. Fifteen of the participants who stepped away continued on to complete at least some of the optional game levels, whereas 20 of the participants only went on to complete the mandatory game levels and 3 of the participants did not complete all of the the mandatory game levels. Ten of the 15 participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game levels. See Table 18. Recall that in the Spring 2017 semester, only 4 of the 25 participants who stepped away and completed some of the optional levels, did so after they completed the mandatory game levels and in the Fall 2017 semester, all of the participants who completed one or more of the optional game levels and who stepped away did so before they completed all of the mandatory game

levels.

As mentioned earlier, it is the promise of some course credit that draws students who have stepped away back into the game and some of these students do go on to complete more optional levels. Without this hook back to course credit, students are less likely to return to the game.

Table 26: Spring 2018 Number of Participants Who Stepped Away by Number of Times

# Times	All Sections	F2F1	F2F2	UOL
0	192	90	30	72
1	31	13	8	10
2	2	0	2	0
3	1	0	1	0

Table 27: Spring 2018 Number of Participants Who Stepped Away By Level Completed

Levels Completed	All Sections	F2F1	F2F2	UOL
Some Mandatory	3	1	0	2
Only Mandatory	16	4	7	5
One or More Optional	15	8	4	3
All Optional	11	6	3	2

3.7.3 Discussion

The Command-Line Hacker game did successfully motivate between 32.9% and 60.98% of students in the Spring 2018 semester to complete not only the mandatory levels but also one or more of the optional levels. Furthermore, the 60.98% completion rate was much closer to the 89.06% highest observed completion rate in the Spring 2017 semester, suggesting that the latter was not as much an outlier as originally thought.

Additionally, 85.9% of the students who went beyond the mandatory levels finished

the exercise in a single sitting compared with 84.2% of the students who did not go on to do any optional levels. This suggests that the students who did one or more optional levels may have been slightly more engaged in the exercise or found it easier and/or had prior experience with BASH commands.

However, the students who completed one or more of the optional levels spent an average of 4.44 more minutes in the game despite the fact that the optional levels were far more difficult than the mandatory levels (see tables 1 and 2). This suggests that students who went beyond the mandatory levels may have been quicker than their counterparts who only completed the mandatory levels or may have been more engaged or less distracted. Nonetheless, even though students who went beyond the mandatory levels did not spent a significant amount of additional time in the game, the optional levels required students to use more complex BASH commands and provided additional practice opportunities.

3.7.4 Aggregate Results

Across all three semester of the study, the Command-Line Hacker game successfully motivated students to complete not only the mandatory levels but also one or more of the optional levels. In fact, between 25.68% and 71.88% of participants completed all of the optional levels and between 31.91% and 89.06% of participants completed one or more of the optional levels even though they would not earn any course credit for doing so. See figure 3.

Of the 604 total participants, 25 (4.1%) of the participants completed some mandatory game levels, 299 (49.5%) of the participants completed only the mandatory levels,

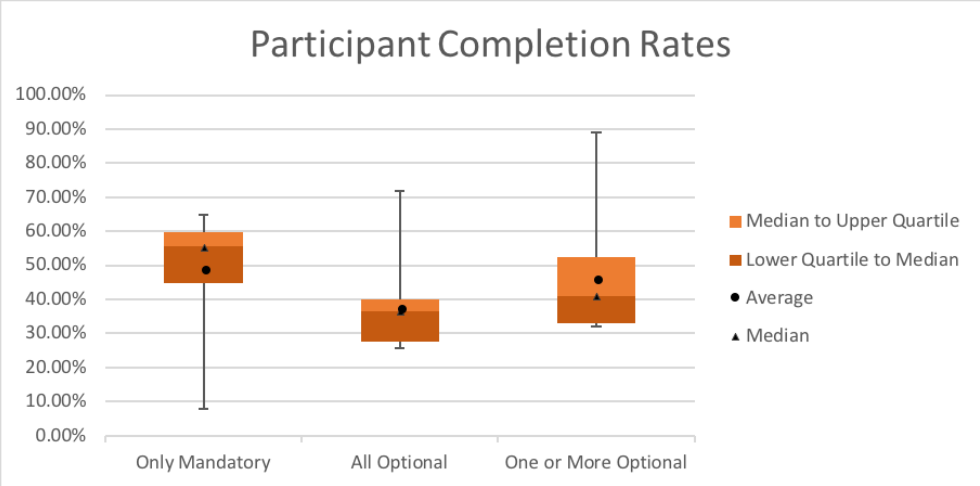


Figure 3: % Participant Completion Rates

279 (46.2%) of the participants completed one or more of the optional levels, and 233 (38.6%) completed all of the optional levels.

The average completion time was 38.13 minutes for students who completed only the mandatory game levels, 40.92 minutes for students who completed one or more of the optional game levels and 40.46 minutes for students who completed all of the optional levels. This slight *decrease* in average completion times despite the fact that the optional levels were far more difficult than the mandatory levels (see tables 1 and 2) suggests that students who went beyond the mandatory levels may have been quicker than their counterparts who only completed the mandatory levels. See figure 4.

Across all semesters, 453 of the 604 participants (75%) submitted the exercise without stepping away at all. One-hundred and ninty-four (194) of 233 participants (83.3%) who completed all of the optional levels did not step away at all and, instead, finished the exercise in a single sitting.

Of the 61 participants who stepped away at least one time and who completed one

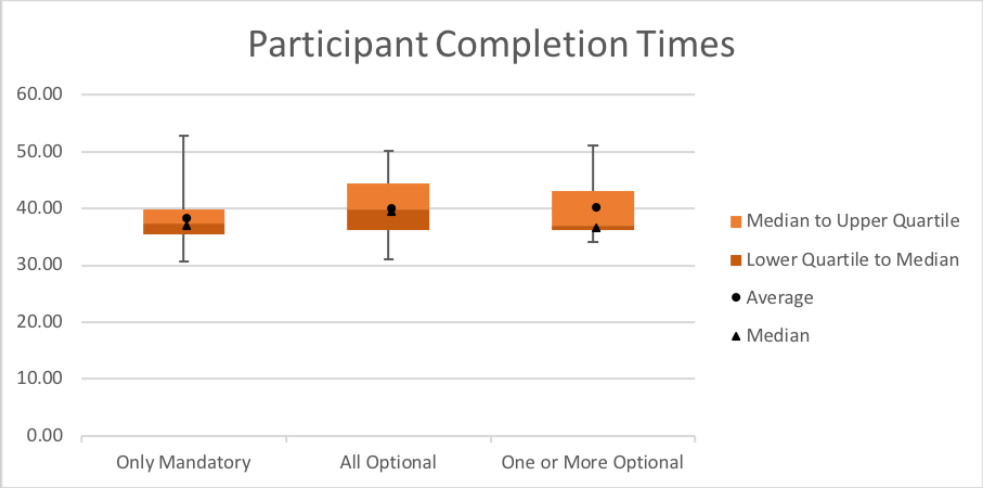


Figure 4: Average Participant Completion Times

or more of the optional levels, only 4 participants (6.6%) did so after they completed all of the mandatory levels and then returned to complete one or more of the optional levels. For the most part, however, participants who stepped away only returned if they had not yet finished the mandatory levels, which suggests that the students were sufficiently motivated to continue playing the game but were not motivated enough to return to the game without the promise of course credit. As such, games with optional levels should be designed such that students are more likely to take a break before getting through all of the mandatory levels.

3.8 Demographic Data Analysis

I explored demographic relationships and correlations with the number of questions completed and the completion times across all three semesters of the study. I detail the tests I performed below but to summarize, there was only one slightly significant correlation between GPA and the number of questions completed. Otherwise, there were no relationships or correlations found between demographic data and the number

of questions completed or the completion time.

3.8.1 Gender

A two-tail T-test did not reveal significant differences between male and female students with regard to the mean number of questions answered (male $\mu = 8.199$, female $\mu = 8.197$, p-value = 0.99) or the mean time to completion for the exercise (male $\mu = 39.1$, female $\mu = 40.0$, p-value = 0.69).

Regression analysis revealed that the relationship between gender and the number of questions was insignificant (significance = 0.733121348) and gender only accounted for about 0.02% of the change in the number of questions completed (R-square = 0.000193595).

Furthermore, the relationship between gender and the time taken was insignificant (significance = 0.964783204) and gender only accounted for about 0.00033% of the change in the time taken (R-square = 3.24629E-06).

3.8.2 Race/Ethnicity

Regression analysis revealed that the relationship between race/ethnicity and the number of questions was insignificant (significance = 0.484493017) and race/ethnicity only accounted for about 0.08% of the change in the number of questions completed (R-square = 0.000813545).

Furthermore, the relationship between race/ethnicity and the time taken was insignificant (significance = 0.925237238) and race/ethnicity only accounted for about 0.001% of the change in the time taken (R-square = 1.46639E-05).

3.8.3 Age

Student ages were divided into the three categorical groups before running regression analysis: 18 - 24, 25 - 30, and 31 & up.

The analysis revealed that the relationship between age and the number of questions was insignificant (significance = 0.039352177) and age only accounted for about 0.07% of the change in the number of questions completed (R-square = 0.007045167).

Furthermore, the relationship between age and the time taken was insignificant (significance = 0.000909817) and age only accounted for about 1.8% of the change in the time taken (R-square = 0.018155618).

3.8.4 GPA

Student GPA was divided into the three categorical groups before running regression analysis: less than 3.0, 3.0 - 3.4, and 3.5 & up.

The analysis revealed that the relationship between GPA and the number of questions was significant (significance = 0.000310807) and that GPA accounts for about 2.1% of the change in the number of questions completed (R-square = 0.021422646).

The students with a GPA greater than or equal to 3.5 were more likely to complete all of the optional game levels (48.91%) when compared to students with a GPA less than 3.0 (29.9%). Nonetheless, even amongst the students with a GPA of less than 3.0, 41.7% completed one or more of the optional levels. See Table 28.

The relationship between GPA and the time taken was insignificant (significance = 0.212592619) and GPA only accounted for about 0.26% of the change in the time taken (R-square = 0.002583969).

Table 28: Questions Completed by GPA

Levels Completed	**<3.0**	**3.0 - 3.4**	**>= 3.5**
Some Mandatory	5.8%	5.17%	1.09%
Only Mandatory	52.4%	51.3%	44.57%
One or More Optional	41.7%	43.5%	54.35%
All Optional	29.9%	37.5%	48.91%

3.9 Student Perceptions

Student perceptions of the Command-Line Hacker game were captured in a survey at the end of each study. In total, the survey was completed by 261 students regarding their perceptions of the Command-Line Hacker game. Additionally, 18 students who were in the badge condition of Spring 2017 completed questions regarding their perceptions of use of badges. See appendix A for the survey.

Students were asked the extent to which they agreed with the following statements on a scale of 1 to 4 with 1 representing "strongly disagree" and 4 representing "strongly agree":

1. The puzzles were a good addition to the course.
2. I wished we could have done more puzzles in the course.
3. The puzzles increased my motivation to learn the topic(s).
4. The puzzle format increased my motivation to complete more puzzles than what was required for course credit.

Of the responses, 85.23% of the 237 students who responded to the statement "The puzzles were a good addition to the course" either agreed or strongly agreed.

Of the responses, 77.64% of the 237 students who responded to the statement "I wished we could have done more puzzles in the course" either agreed or strongly agreed.

Of the responses, 81.86% of the 237 students who responded to the statement "The puzzles increased my motivation to learn the topic(s)" either agreed or strongly agreed.

Of the responses, 68.35% of the 237 students who responded to the statement "The puzzle format increased my motivation to complete more puzzles than what was required for course credit" either agreed or strongly agreed. As this number was higher than the percent of students who actually did complete more than the required levels, the survey respondents may have been more positive about the game in general. See Figure 5.

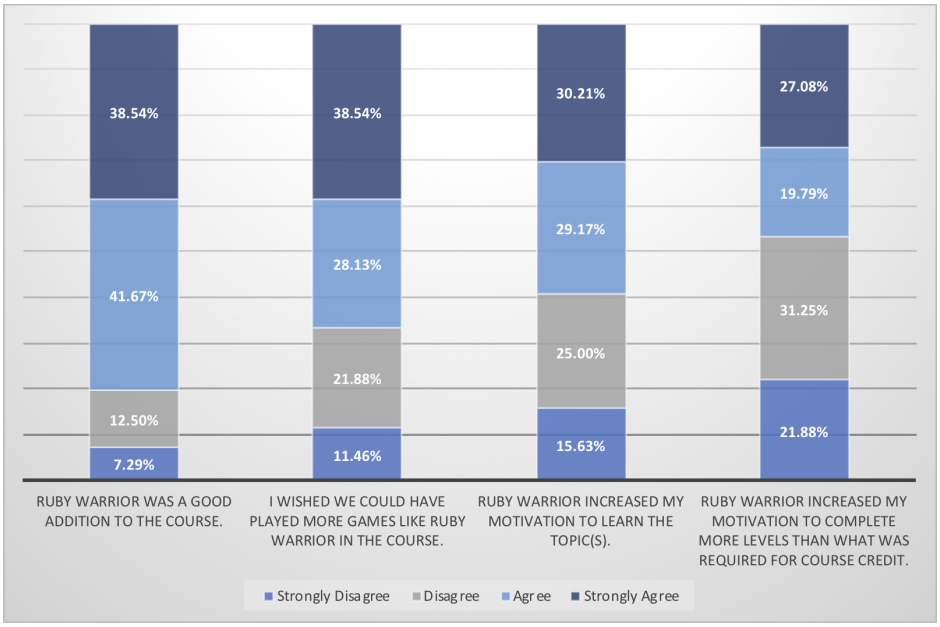


Figure 5: Quantitative Survey Results

The survey also asked what students liked about the game puzzles. What follows

is a categorization of the 155 student comments into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54]. For each category, I explain the words and phrases that I looked for in order to categorize the comment into one of the motivational mechanisms. I acknowledge that as this analysis was done by myself, there is the possibility of experimenter bias. However, I endeavored to capture the intent behind each comment as impartially as possible.

Autonomy (SDT)/Control (U&G)

Of the responses, 5% (8/155) demonstrated an autonomy or control motivational mechanism. These comments indicated that the game gave them the freedom to experiment without penalty and included words and phrases such as "trial and error", "less pressured", "go at your own pace", or otherwise indicated that students felt the game left them feeling that they could experiment without fear of it impacting their grade. Two example comments from participants in the study are as follows:

> *"I enjoyed how they allowed for trial and error thinking process which is too often punished in academic environments due to limitation of attempts on assignments."* - P3

> *"There were immediate results that did not effect my grade and it allowed for me to try to reach the goal on my own time. The style motivated me to keep searching and trying different ideas to get the result the best."* - P73

Competence (SDT)/Challenge (U&G)

Of the responses, 41% (63/155) demonstrated a competence or challenge motivational mechanism. These comments indicated that the game provided a challenge and helped them learn the material and included words and phrases such as "unlocking the next level", "challenge", "learn", "required you to think", or otherwise indicated that students felt the game left them feeling challenged and accomplished for having solved each level. Two example comments from participants in the study are as follows:

> *"They were challenging at first but it was fun to overcome the challenge and learn."* - P87

> *"I really liked that it helped me learn the commands for Linux without having to think about it because I was focused on unlocking the next level. It felt like I was playing like a Doors game where you have to find the clue in the room to unlock the door and continue. I liked it a lot and would've completed more if time allowed."* - P99

Competition (U&G)

One of the responses demonstrated a competition motivational mechanism in that they expressed that the game *"made it feel like a small competition"* - P144.

Fantasy (U&G)

Of the responses, 3.2% (5/155) demonstrated a fantasy motivational mechanism in that they expressed that they enjoyed the hacking theme. These comments explicitly

expressed that the student enjoyed playing the role of the hacker. Two example comments from participants in the study are as follows:

> *"I felt like a real hacker, not like how it's portrayed in the movies but how in reality things would occur."* - P19

> *"...the whole 'hacking' theme to the assignment made it more appealing."* - P38

Interest (U&G)

Of the responses, 43% (66/155) demonstrated an interest motivational mechanism. These comments indicated that the game was "interesting" and included words such as "fun", "engaging", "interactive" "entertaining", "not boring" and so forth. Two example comments from participants in the study are as follows:

> *"I liked that it gave a fun incentive for understanding and using Linux commands. I solidify information so much better this way, rather than just memorizing facts."* - P76

> *"the puzzles were actually entertaining and it felt more like recreation then frustrating academia."* - P113

Diversion (U&G)

Of the responses, 11% (17/155) demonstrated a diversion motivational mechanism in that they expressed that the game provided a break from typical homework assignments. These comments indicated that the game provided a "change of pace" from the norm in the class and included words such as "different", "unique", "atypical",

or otherwise indicated that they provided a "break" from the day to day coursework. Two example comments from participants in the study are as follows:

> *"It was a little creative and different then the work we have been doing. Changing it up a little sometimes help break up the material and makes it a little more fun for people to learn."* - P104

> *"they were different from what you normally do in class and seemed like a better way to learn linux commands"* - P135

Relatedness (SDT)/Social Interaction (U&G)

None of the responses demonstrated a relatedness or social interaction motivational mechanism.

3.9.1 Discussion

A higher percentage of the students who completed the survey either agreed or strongly agreed that the game was a good addition to the course and that they improved motivation to learn the topic than those who disagreed or strongly disagreed, which was a stark contrast with the negative feedback received on the non-gamified BASH exercises in previous semesters.

Additionally, student comments on the survey revealed a range of motivations for playing the game which could be aligned with the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54]. This suggests that the game satisfied basic psychological and emotional needs and, therefore, led to a high percent of students to continue past the levels required for course

credit.

Furthermore, of these motivations, interest(engagement) and challenge/competence comments were, by far, the most prevalent, which suggests that students may have completed more than the mandatory levels because they were interested or felt challenged. While I did not examine learning outcomes in this study, challenge, one of the two main elements in flow states along with engagement, was found by Hamari et al. [26] to have a particularly strong correlation to learning outcomes.

3.10 Badges

In Spring 2017, 18 participants responded to the survey about their perceptions of badges. These students were asked similar questions regarding the badges as they were asked about the game in general, the results of which are shown in Table 29:

1. The badges were a good addition to the course.

2. I wished we could have earned more badges in the course.

3. The badges increased my motivation to learn the topic(s).

4. The badges increased my motivation to complete the supplemental exercise(s).

Of the responses, 78.6% of the 14 students who responded to the statement "The badges were a good addition to the course" either agreed or strongly agreed.

Of the responses, 71.4% of the 14 students who responded to the statement "I wished we could have earned more badges in the course" either agreed or strongly agreed.

Of the responses, 71.4% of the 14 students who responded to the statement "The badges increased my motivation to learn the topic(s)" either agreed or strongly agreed.

Of the responses, 71.4% of the 14 students who responded to the statement "The badges increased my motivation to complete more puzzles than what was required for course credit" either agreed or strongly agreed. See Table 29.

Table 29: Badges Quantitative Survey Results

Answer Choice	**Question 1**	**Question 2**	**Question 3**	**Question 4**
1	1 (7.1%)	1 (7.1%)	2 (14.3%)	1 (7.1%)
2	2 (14.3%)	3 (21.4%)	2 (14.3%)	3 (21.4%)
3	5 (35.7%)	3 (21.4%)	5 (35.7%)	3 (21.4%)
4	6 (42.9%)	7 (50%)	5 (35.7%)	7 (50%)

Of the responses, 2 of 8 respondents to the "What did you like about using badges in Canvas?" question mentioned that the badges boosted motivation or encouraged them to go beyond the required levels. One of these comments was as follows:

> *"Good way to boost confidence and motivation!"* - P2

Of the responses, 4 of 5 respondents to the "What didn't you like about using badges in Canvas?" question mentioned that the badge did not have any underlying incentive for achieving them, such as extra points in the course. One of these comments was as follows:

> *"They don't really mean much. Maybe some sort of extra credit or something for getting higher level badges would add to the incentive of doing well on the assignments."* - P1

3.10.1 Discussion

The survey results do indicate that some students found badges to be motivational and, as such, they could have contributed to the high completion rates of the online class in the Spring 2017 class. However, it is important to note that the percent of students who were agreed or strongly agreed with the aforementioned statements about badges were lower than those who responded similarly to the statements about the game itself.

However, while the completion rates of one section of the face-to-face class in the final semester of the study were much higher than otherwise seen in non-badged sections, the badged section still had far higher completion rates than seen at any other point in the study. This seems to suggest that badges did contribute. However, there were too many confounds to determine the precise impact of badges and the response rate was low for this survey. As such, more research is needed in this area to isolate the effect of badges.

3.11 Limitations

I had originally intended for one of the face-to-face sections to use badges in the Spring 2017 semester of the study in order to compare their impact with the other face-to-face section. However, the instructor of this section was unable to get the badges set up before the study. Additionally, when I tried to incorporate badges again in the Spring 2018 semester, the CanvaBadges plug-in was no longer available. As such, although the results in the survey did show some promising indications, I was unable to determine any conclusive findings on the impact of badges on the

completion rates of the optional puzzles.

Also, as I inserted only a single puzzle exercise into a semester-long course, I could not account for how much my results have to do with the novelty of a single game intervention. As pointed out, 11% of the student comments on the survey indicated that they enjoyed the break from regular classwork. Finally, this study was wholly focused on student motivation and did not address learning outcomes at all.

3.12 Conclusions and Future Work

With regard to my first research question, "Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R1), my results clearly show that in this instance, yes they did. A percentage of students did go on to complete one or more of the optional puzzles. Furthermore, student survey results indicated that they were motivated to not only complete the optional game levels, but also to learn the topic itself. These results are promising, but need further investigation to more deeply understand how and when such games can engage students.

It is also important to note that there was no demographic correlation between completion times or levels and race/ethnicity, age, or gender but that there was a correlation found between completion levels and student GPA. More analysis would need to be done to determine why this is the case and whether or not this had an impact on the relatively faster completion times for students who went beyond the mandatory levels.

As mentioned earlier, the results suggest that games should be designed such that

students are more likely to take a break before getting through all of the mandatory levels as students tended to not return if they took a break. Therefore, in future studies, it would be helpful to examine how changing the number of mandatory levels assigned would impact the number of optional game levels that students would complete. Additionally, it would be interesting to add more optional levels to try to discern the upper limit in terms of time students would spend on co-curricular, not-for-credit practice.

While I was only able to gather survey results on my research question "Which game elements (leaderboards, badges etc.) provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R2) I did discover that students felt the badges motivated them to go beyond the required levels and, to a lesser degree than the game itself, motivated them to learn the topic. However, there were too many confounding variables to isolate just how much further badges incentivized students. In future studies it would be helpful to attempt to isolate the badge effect, perhaps with a between-subjects study design and to add a survey question to try to identify students who were competition-averse and, as such, disincentivized by badges. Additionally, it would be interesting to study the impact of attaching some real-world reward to the badges to make them more meaningful to the students.

Finally, it is important to note that unlike Schreuders' and Butterfield's [53] study of a gamified cybersecurity module, this intervention did not lead to any increase in grading or instructional load on the course instructors. Once the exercise was set up, it was completely auto-graded and therefore required only minimal intervention by instructors if badges were to be awarded.

CHAPTER 4: INCREASING PROGRAMMING PRACTICE WITH A SERIOUS GAME

Learning a new programming language can be particularly demanding for computer science students as proficiency necessitates repetitive practice. In this study, I investigate whether a serious game can motivate students to practice technical programming skills beyond what was required for course credit over a longer period of time than the game in the previous study.

This chapter depicts a two semester study where I mainly concentrate on the first research question (see Section 1.4): "Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R1) However, additional questions in the survey posed after the Spring 2018 semester of the study focus on the second research question: "Which game elements (leaderboards, badges etc.) provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R2)

I ran the study over two semesters. The Fall 2017 semester of the study provided a baseline for student willingness to engage in additional practice even after they have satisfied for requirements for course credit. I also explored student perceptions of using serious games to learn programming in an online survey.

In the Spring 2018 semester, I more deeply assessed student engagement in programming practice by capturing student attempts and time spent on each level of

the game. Furthermore, some additional questions were asked in the survey about the leaderboard to try to address its effect on student engagement to go above and beyond course requirements.

4.1 Setting

At the University of North Carolina at Charlotte, students in the Software Engineering course, a large class that is required of all Bachelor of Science in Computer Science students at the University of North Carolina at Charlotte, learn Ruby and the Rails framework as the tools for applying software engineering principles. See Appendix G for course information. Students in my section of the course spend the second half of the semester developing a full-stack web application in Agile teams.

Ruby is significantly different from the Java students learn in their Freshman and Sophomore computing courses, and so we spend the first six weeks of the course learning the language in parallel with software engineering principles. However, as software engineering principles and not the programming language or framework are the primary learning objectives, it is important for students to practice on their own.

In past semesters, I have used Codecademy [9] and SoloLearn [55] tutorials along with some hands on, in class, exercises. However, it was clear that students needed some additional practice outside of class time, making this an ideal situation for examining the impact of games on motivating students to engage in programming practice beyond course requirements.

4.2 Game

Ruby Warrior [2], an interactive game designed by Ryan Bates to teach the Ruby programming language as well as some artificial intelligence concepts, includes points and levels, but also includes key game elements such as competition and challenges in the form of foes to defeat and captives to rescue. This game was classified by Vahldick et al. [59] as a general type of game that emphasizes code writing in their review of games to improve computer programming competency. This general games category includes several types, such as simulations, real time strategies and maze games.

In this game, which is installed via a Ruby gem (library), students write Ruby code that will enable their warrior to climb a tower to reach a precious Ruby at the top. On each floor of the tower, they must write code that will instruct their warrior to reach the stairs to the next floor, battling enemies and rescuing captives along the way. The level instructions, provided in a README file that updates each time they clear a level, gives players a sense for what each floor contains, but it is up to the students to program enough artificial intelligence into their warrior to find their own way. See Figure 6(a).

Once a player writes code that they believe will provide the artificial intelligence for their warrior to clear the level, they run the Ruby Warrior command and can watch as their warrior attempts to make its way to the stairs for that level. Once a level is cleared, the cumulative score and level is displayed. See Figure 6(b).

There are ten floors of the tower to clear to reach the top and two levels of difficulty: beginner and intermediate. The beginner level 1 requires only the use of a single line

README

```
Level 2

It is too dark to see anything, but you smell sludge nearby.

Tip: Use warrior.feel.empty? to see if there is anything in front of you,
and warrior.attack! to fight it. Remember, you can only do one action
(ending in !) per turn.

 --------
|@   s  >|
 --------

  > = Stairs
  @ = Warrior1 (20 HP)
  s = Sludge (12 HP)


Warrior Abilities:

  warrior.feel
    Returns a Space for the given direction (forward by default).

  warrior.attack!
    Attacks a unit in given direction (forward by default).

  warrior.walk!
    Move in the given direction (forward by default).


When you're done editing player.rb, run the rubywarrior command again.
```

(a) Ruby Warrior README

```
Warrior1 attacks forward and hits Sludge
Sludge takes 5 damage, -3 health power left
Sludge dies
Warrior1 earns 12 points
- turn 7 -
 --------
|   @   >|
 --------
Warrior1 walks forward
- turn 8 -
 --------
|    @  >|
 --------
Warrior1 walks forward
- turn 9 -
 --------
|     @ >|
 --------
Warrior1 walks forward
- turn 10 -
 --------
|      @>|
 --------
Warrior1 walks forward
Success! You have found the stairs.
Level Score: 12
Time Bonus: 10
Clear Bonus: 4
Total Score: 10 + 26 = 36
```

(b) Clearing a Level in Ruby Warrior

Figure 6: Ruby Warrior Game Play

of code with the warrior.walk! method, whereas level 10 requires the use of loops, conditionals and other programming logic along with strategic use of game objects and methods:

1. Actions
    - warrior.walk! - move in given direction
    - warrior.attack! - attack the unit in given direction
    - warrior.rest! - gain 10% of max health back, but do nothing more
    - warrior.bind!- bind unit in given direction to keep him from moving (forward by default)
    - warrior.rescue! - rescue a captive from his chains (earning 50 points) in given direction
2. Senses
    - warrior.feel - returns a Space for the given direction
    - warrior.health - returns an integer representing your health
    - warrior.distance - returns the number of spaces the stairs are away
    - warrior.listen - returns an array of all spaces which have units in them

3. Spaces

    - space.empty? - if true, this means that nothing (except maybe stairs) is at this location and you can walk here
    - space.stairs? - determine if stairs are at that location
    - space.enemy? - determine if an enemy unit is at this location.
    - space.captive? - determine if a captive is at this location
    - space.wall? - returns true if this is the edge of the level. You can't walk here
    - space.ticking? - returns true if this space contains a bomb which will explode in time
    - space.golem? - returns true if a golem is occupying this space.

The Ruby Warrior gem/library contains a warrior and a space object with methods for the actions performed by the warrior or for queries about the playing space in front of the warrior. Ruby uses dot syntax like C or Java does for objects and methods, but has a few unique short cuts, such as being able to add a ? at the end of a method call in lieu of writing a boolean operation. Ruby, like the C language allows objects to be passed by value or passed by reference where the object itself is passed rather than just its value. Adding a ! to a method call will pass the object by reference in Ruby. You can see the ! and ? in use in the above list of objects methods. Additionally, players not only control their warrior but may also discover the ability to control a 'golem' unit to help them defeat each level.

RubyWarrior has been mentioned in a number of academic papers that review games designed to help improve programming or computing competency [59][39][37]. However, none of these papers study the game itself.

4.3 Design

As elucidated in section 2.1.3, Ibanez et al.'s [30] results indicate that students continued working on C programming activities even after earning the maximum possible score for their class in a gamified learning platform called Q-Learning-G. In this platform, game mechanisms included a leaderboard and badge and phase showcases where students achievements were displayed. Study results indicated that 50% of the participants in this study performed more than 29% additional work beyond the requirements for maximum scores on course activities.

The aforementioned study examines a gamified intervention rather than a serious game. I wanted to see if similar results in terms of engaging students in practice beyond course requirements could be achieved with a serious game. I also wanted to examine the time effect to see whether students would continue to play the game in subsequent weeks, even though they would not earn course credit for doing so.

As my intention was to see if students would be motivated to do more than was required for course credit, I collected data on how many levels students completed to determine how many students went beyond the required levels. Additionally, looked at the total time that students spent on the exercise to see if those who did more than the required levels would spend more time-on-task doing so.

4.4 Procedures

Students were introduced to the basics of Ruby during weeks 1 and 2 of the semester using the Ruby Tutorial SoloLearn course [55] and in-class exercises. SoloLearn is a free Android, iOS and Web platform that provides courses that teach the basics of

several programming languages, including Ruby. In week 3, I introduced the Ruby Warrior game during class where students were encouraged to work with their light-weight teams to defeat the levels in the game. Students submitted their game progress to an assignment created in UNCC's Learning Management System, Canvas. In this assignment, students were provided installation and grading instructions with a deadline set for the end of the week. Students were required to complete up to level 3 for full course credit but were told that a leaderboard would be posted with the top ten student scores.

In the Fall 2017 semester of the study, students submitted screenshots with their earned final score for each level. In the Spring 2018 semester of the study, the students submitted time-stamped logs of all in-game interactions.

Students were encouraged to continue to play for four more weeks as a way to prepare for the first course test and for a chance to improve their standing on the leaderboard. They submitted game progress to Canvas in these subsequent weeks, but did not receive course credit for additional levels and/or higher scores achieved. A leaderboard was posted to the Canvas course home page and was highlighted in class to encourage students to continue to play.

Survey comments in the Fall 2017 semester of the study revealed an unexpected consequence of the leaderboard: some students continued to play but did not submit their scores as they knew they had not yet achieved a high enough score to earn a place on the leaderboard. As a result, in the Spring 2018 semester of the study, 5 course points could be earned for submitting logs, regardless of whether or not students continued to play.

During week 8 of the course, I sent a recruitment email for students to complete a brief online survey about the exercise. Students were required to consent to participate in the anonymous survey, which included some basic demographic questions as well as questions about computer, mobile and board game behaviors, level attained in the game, perceptions about the game and about how the game and the leaderboard impacted the students' motivation to continue playing. See appendix B for the survey. Student comments were categorized into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54] in an effort to capture how the game motivated students.

My study methods and data collection were approved by the University of North Carolina at Charlotte's Institutional Review Board (IRB Number: 17-0025). See appendix H.

4.5 Fall 2017

4.5.1 Participants

Study participants were students in one section of the Fall 2017 Software Engineering course.

The sample was comprised of 76 computer science majors aged 19-36 ($\mu = 22.66$, $\sigma = 3.5$). Among the participants, 67 (88.2%) were male and 9 (11.8%) were female. The grade point average (GPA) of the participants ranged from 2.12 to 4.0 ($\mu = 3.2$, $\sigma = 0.50$). The race/ethnicity demographics of the participants are shown in Table 30.

With respect to game playing behaviors, of 38 survey respondents, 6 (15.8%) reported that they did not play recreational computer or mobile games, 5 (13.2%)

Table 30: Race/Ethnicity Demographics (Fall 2017)

Race/Ethnicity	# Participants
African American	6
American Indian	1
Any 2 or More Races	2
Asian or Pacific Islander	16
Caucasian	40
Hispanic	3
International	1
Not Specified	7

reported that they played more than 0 but less than 3 hours per week, 12 (31.6%) reported that they played 3 to 7 hours per week, and 15 (39.5%) reported that they played more than 7 hours per week. These survey respondents spent far less time playing board games each week, with 21 (55.3%) reporting that they did not play them, 13 (34.2%) reporting that they played more than 0 but less than 3 hours per week, 3 (7.9%) reporting that they played 3 to 7 hours per week, and 1 (2.6%) reporting that they played more than 7 hours per week. See Table 31.

Table 31: Game Playing Behaviors of Respondents (Fall 2017)

Hours / Week Playing	# Participants	
	Digital Games	Board Games
None	6 (15.8%)	21 (55.3%)
More than 0 but less than 3 hours per week	5 (13.2%)	13 (34.2%)
3 to 7 hours per week	12 (31.6%)	3 (7.9%)
Greater than 7 hours per week	15 (39.5%)	1 (2.6%)

4.5.2 Results

The primary measures for this semester of the study were the number of game levels completed by the students in the class over all and the game levels completed in subsequent weeks to assess the time impact. In all, the results were promising

as students did spend additional time completing more levels than were assigned for course credit.

4.5.2.1 Level Completion Rates

As illustrated by Table 32, which summarizes the completion rates of the mandatory versus optional game levels, 42.1% of the students completed one or more optional game levels. All but 1 student were able to complete the levels assigned for course credit and 56.6% of participants completed only the mandatory levels. Four students (5%) completed all ten of the beginner levels to earn the top spots on the leaderboard.

Table 32: Level Completion (Fall 2017)

Levels Completed	**# Participants**	**% Participants**
Fewer than Mandatory	1	1.3%
Mandatory	43	56.6%
1 or More Optional	32	42.1%

4.5.2.2 Participation Over Time

Recall that studies have found a time effect with games and gamification, where the positive effective decreases over time [40][43]. In terms of participation over time in this semester of the study, the majority of the students (78.95%) stopped reporting their progress after the first week. These results are depicted in Table 33 and in Figure 7. However, 21% of the participants reported earning higher scores/levels in subsequent weeks. In each subsequent week, there was a different subset of participants from the previous week. Some of the later participants skipped a week or more before participating again.

It is uncertain exactly how many continued to play beyond week one due to the

unexpected consequence of the leaderboard - surveys indicated that at least some students who did not earn a high enough score to make it into the leaderboard continued to play the game. Nonetheless, the leaderboard standings shifted in weeks 1 through 4 of the study as students submitted their scores.

Table 33: Weekly Reported Participation (Fall 2017)

Week	# Participants	% Participants
1	60	78.95%
2	11	14.47%
3	4	5.26%
4	1	1.32%
5	0	0.00%

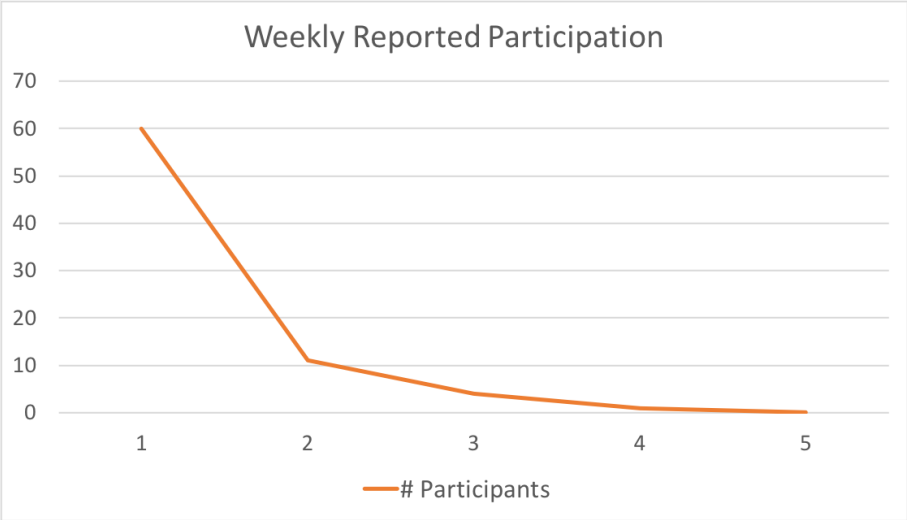


Figure 7: Weekly Reported Participation (Fall 2017)

4.5.2.3 Test Performance

There was no direct correlation found between the participants' performance on the Ruby questions on the first test and the game level attained (correlation coefficient = 0.15).

While the mean score on the test for the students who completed one or more

optional game levels was slightly higher (58.12%) than for the students who only completed the mandatory levels (51.09%), this difference was not found to be statistically significant (p-value = 0.076).

4.6 Spring 2018

In the Spring 2018 semester of the study, I captured console logs in order to analyze time data and attempts in addition to level completion rates, test performance and participation over time. I also added a survey question that would delve more deeply into motivations for continuing to play beyond the level required for course credit.

4.6.1 Participants

Study participants were students in one section of the Spring 2018 Software Engineering course.

The sample was comprised of 109 computer science majors (aged 19-38, $\mu = 22.7$, $\sigma = 3.1$). Among the participants, 87 (79.8%) were male and 22 (20.2%) were female. The grade point average (GPA) of the participants ranged from 1.97 to 4.0 ($\mu = 3.2$, $\sigma = 0.54$). The race/ethnicity demographics of the participants are shown in Table 34.

Table 34: Race/Ethnicity Demographics - Spring 2018

Race/Ethnicity	**# Participants**
African American	11
Any 2 or More Races	6
Asian or Pacific Islander	9
Caucasian	47
Hispanic	6
International	5
Not Specified	25

With respect to game playing behaviors, of the survey respondents, 14 (23.73%)

reported that they did not play recreational computer or mobile games, 12 (20.33%) reported that they played more than 0 but less than 3 hours per week, 17 (28.81%) reported that they played 3 to 7 hours per week, and 16 (27.12%) reported that they played more than 7 hours per week. These survey respondents spent far less time playing board games each week, with 44 (74.58%) reporting that they did not play them, 11 (18.64%) reporting that they played more than 0 but less than 3 hours per week, 4 (6.78%) reporting that they played 3 to 7 hours per week, and 0 (0.0%) reporting that they played more than 7 hours per week. See Table 35.

Table 35: Game Playing Behaviors of Respondents - Spring 2018

Hours / Week Playing	**# Participants**	
	Digital Games	**Board Games**
None	14 (23.73%)	44 (74.58%)
More than 0 but less than 3	12 (20.33%)	11 (18.64%)
3 to 7	17 (28.81%)	4 (6.78%)
Greater than 7	16 (27.12%)	0 (0.0%)

4.6.2 Results

The primary measures for this semester of the study were the number of game levels completed by the students in the class over all, the number of attempts and time to complete each level, and the game levels completed in subsequent weeks to assess the time impact. In all, as with the Fall 2017 semester of the study, the results were promising in that students did spend additional time completing more levels than what was assigned for course credit.

4.6.2.1 Level Completion Rates

As illustrated in Table 36, which summarizes the completion rates of the mandatory versus optional game levels, 43.27% of the students completed one or more optional game levels. All but 1 student were able to complete the levels assigned for course credit and 55.77% of participants completed only the mandatory levels. Seven students (6.73%) completed all ten of the beginner levels to earn the top spots on the leaderboard.

Recall that in the Fall 2017 semester, 42.1% of the students completed one or more optional levels and, as such, completion rates were very consistent between the two semesters.

Table 36: Level Completion - Spring 2018

Levels Completed	**# Participants**	**% Participants**
Fewer than Mandatory	1	0.96%
Mandatory	58	55.77%
1-5 Optional Levels	38	36.54%
All Optional	7	6.73%

4.6.2.2 Participation Over Time

In terms of participation over time, logs revealed that the majority of the students (70.19%) stopped playing after the first week. These results are depicted in Table 37 and in Figure 8. However, 31 (29.81%) participant logs revealed higher scores/levels in subsequent weeks. Of these 31 students, 1 revealed higher scores during three weeks, 8 revealed higher scores during two weeks, and 22 revealed higher scores in one subsequent week. In each subsequent week, there was a different subset of participants from the previous week. Some of the later participants skipped a week or more before

participating again. The leaderboard standings shifted in each of the weeks of the study.

When compared to the results on participation over time in the Fall 2017 semester, more students participated in subsequent weeks in the Spring 2018 semester. However, as mentioned earlier, participation in later weeks in the Fall 2017 was under-reported due to an unexpected consequence of the leaderboard - surveys indicated that at least some students who did not earn a high enough score to make it into the leaderboard continued to play the game.

Table 37: Participation By Week - Spring 2018

Week	# Participants	% Participants
1	73	70.19%
2	19	18.27%
3	10	9.62%
4	7	6.73%
5	5	4.81%

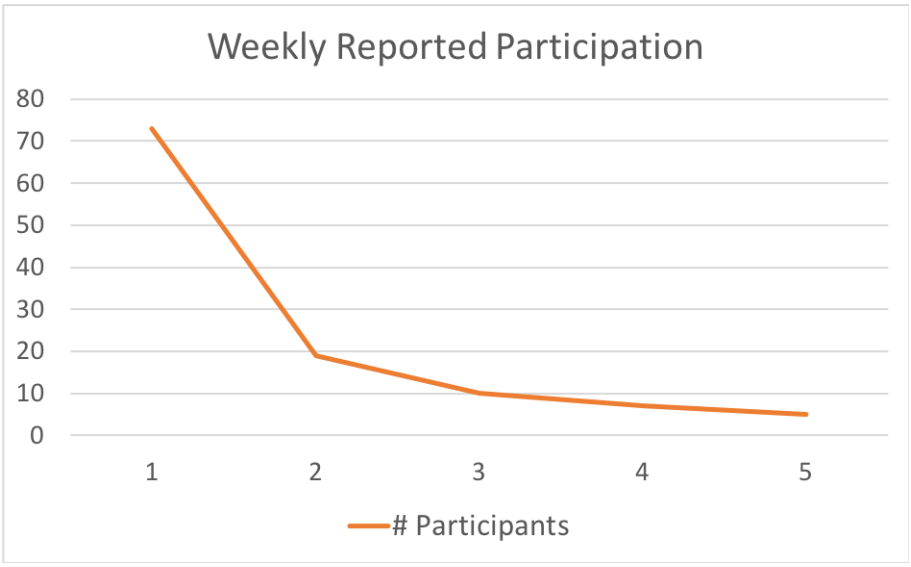


Figure 8: Weekly Reported Participation - Spring 2018

4.6.2.3 Time Spent

The total time students spent in the game was gathered in this study through console logging. As students worked on Ruby Warrior over several weeks, I set a maximum threshold for any attempt at defeating a level of 30 minutes. If students took longer than 30 minutes to run the next Ruby Warrior command, I assumed the student stepped away for hours or days. In this case, the time was replaced with an average attempt time for the class as a whole.

This calculated total time increased according to how many levels they completed. Students who completed only the mandatory levels spent a mean time of 45.74 minutes in the game, those who completed from 1 to 5 extra levels spent a mean time of 100.97 minutes in the game and those who completed the final optional level spent a mean time of 162.43 minutes in the game. These results are depicted in Table 38.

Table 38: Minutes Spent Playing - Spring 2018

Levels Completed	**Mean**
All Mandatory	45.74
Some Optional levels	110.53
1-5 Optional Levels	100.97
All 7 Optional Levels	162.43

This is expected as it would take students longer to complete more levels. However, when mean time per level was calculated, there was no significant difference (p-value 0.2) in the mean minutes per level. Students who completed all of the mandatory levels did so with a mean time of 15.25 minutes per level and students who completed one or more of the optional levels did so with a mean time of 18.02 minutes per level. See Table 39.

4.6.2.4 Level Attempts

An attempt in Ruby Warrior is defined as the player running their new code through the interpreter to see if their warrior has enough artificial intelligence to make it through the level to the stairs. There was no significant difference (p-value 0.9) in the mean attempts per level between students who completed only the mandatory levels and those who completed one or more of the optional levels. Students who completed all of the mandatory levels did so in an average of 6.33 attempts per level and students who completed one or more of the optional levels did so in an average of 6.23 attempts per level. The students who completed all optional levels did so in an average of 7.24 attempts per level. See Table 39.

Table 39: Mean Attempts and Minutes per Level - Spring 2018

Levels Completed	**Mean Attempts/Level**	**Mean Minutes/Level**
All Mandatory	6.33	15.25
1-5 Optional Levels	6.04	18.01
All Optional	7.24	18.05

4.6.2.5 Test Performance

There was no direct correlation found between the participants' performance on the Ruby questions on the first test and the game level attained (correlation coefficient = 0.24), time spent in game (correlation coefficient = 0.24) or total number of attempts in game (correlation coefficient = 0.25).

While the mean score on the test for the students who completed one or more optional game levels was slightly higher (74.4%) than for the students who only completed the mandatory levels (70.4%), this difference was not found to be statistically

significant (p-value = 0.057).

4.7 Discussion

In both studies, the Ruby Warrior game did successfully motivate students to complete not only the mandatory levels but also one or more of the optional levels. In fact, 42.1% of the students in the Fall 2017 semester of the study and 43.27% in the Spring 2018 semester of the study completed 1 or more of the optional levels even though they would not earn any course credit for doing so.

While the test did not show any significant difference between the scores of the students who completed one or more optional levels and those who only completed the mandatory levels, this test was not designed to measure Ruby Warrior learning outcomes. Furthermore, the log data collected in the Spring 2018 semester of the study revealed that students who completed one or more optional levels spent an average of 64.79 additional minutes and an average of 40.31 additional attempts in the Ruby Warrior game than their peers who only completed the mandatory levels. While learning outcomes are not being examined here, time on task was found by Landers and Landers [36] to statistically predict learning outcomes and motivation and engagement are leading indicators for learning outcomes.

The number of participants dropped off after the first week of each of the two studies. In the Fall 2017 semester of the study, participation dropped from 78.98% of all students in the class to 14.47% in week 2, 5.26% in week 3, 1.32% in week 4 and 0 in week 5. In the Spring 2018 semester of the study, participation dropped from 70.19% of all students in the class to 18.27% in week 2, 9.62% in week 3 and 6.73% in

week 4 and 4.81% in week 5. This does seem to support the research suggesting that gamified approaches are more effective in the short-term [40][43]. However, it is also important to note that students who had reached the top level would have had no reason to continue playing, nor would have students who felt they knew enough Ruby to satisify their needs in the course. Furthermore, as there was a different subset of participants in each of the subsequent weeks and as some students took some weeks off before continuing to play it was worthwhile continuing with the game beyond week 1.

Another explanation could be that for weeks 2-5 of the study, there was no course credit available for continuing with Ruby Warrior. It is possible that adding a 'hook' to some small amount of course credit would help draw some additional students back into the game, with the goal being of getting them into a state of focused concentration and increased enjoyment whilst engaged in an intrinsically interesting activity, otherwise characterized as a flow state [10]. More research is needed to determine whether participation in subsequent weeks for this game can be increased.

Nonetheless, my primary goal was accomplished. Ruby Warrior did provide incentive for a number of students to go beyond the requirements for course credit to develop technical skills (R1) in the Ruby programming language.

4.8 Student Perceptions

A survey regarding their perceptions of the Ruby Warrior game was completed by 57% (103) of students in both the Fall 2017 and Spring 2018 studies. Twenty-two percent (40) of students who responded to the survey were from the Fall 2017 study

and 35% (63) were from the Spring 2018 study. See appendix B for the survey.

Students in both studies were asked the extent to which they agreed with the following statements on a scale of 1 to 4 with 1 representing "strongly disagree" and 4 representing "strongly agree":

1. *Ruby Warrior was a good addition to the course.*
2. *I wished we could have played more games like Ruby Warrior in the course.*
3. *Ruby Warrior increased my motivation to learn the topic(s).*
4. *Ruby Warrior increased my motivation to complete more levels than what was required for course credit.*

The percent of the students who responded to each question and to each answer choice is depicted in Figure 9.

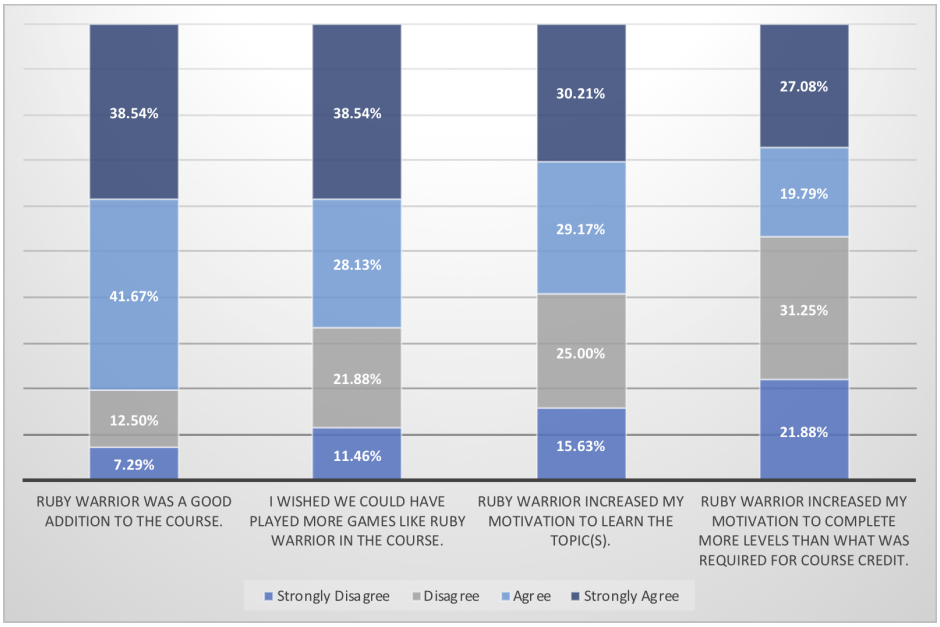


Figure 9: Quantitative Survey Results 1

Students in the second study were asked the extent to which they agreed with the following statements on a scale of 1 to 4 with 1 representing "strongly disagree" and

4 representing "strongly agree". Three example comments from participants in the study are as follows:

1. *Ruby Warrior increased my motivation to continue to play in subsequent weeks*
2. *The leaderboard increased my motivation to complete more levels than was required for course credit.*
3. *The leaderboard increased my motivation to continue to play Ruby Warrior in subsequent weeks.*

The percent of the students who responded to each question and to each answer choice is depicted in Figure 10.

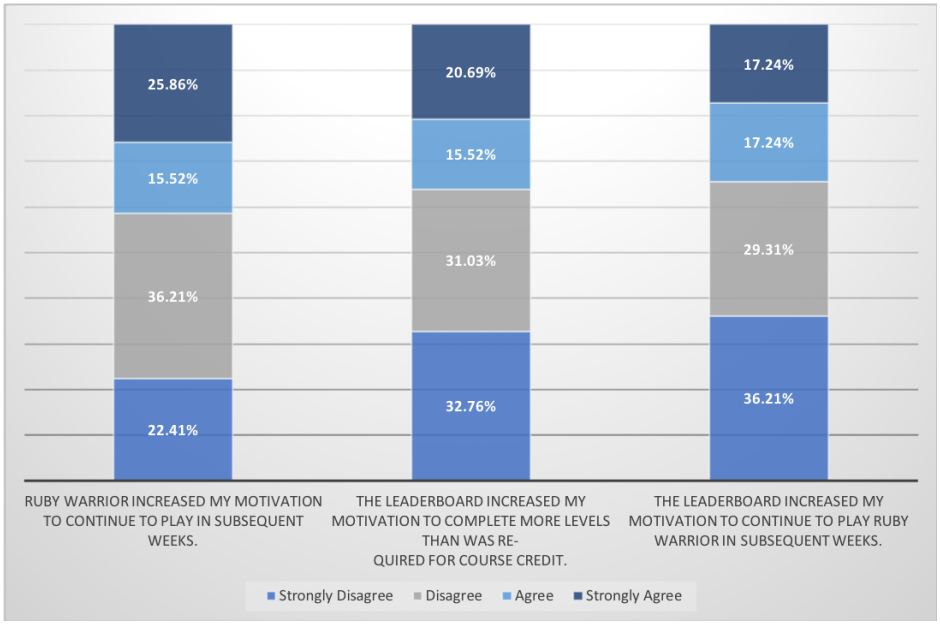


Figure 10: Quantitative Survey Results 2

The survey also asked what students liked about Ruby Warrior. What follows is a categorization of the 69 student comments across both semesters of the study into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54]. For each category, I explain the

words and phrases that I looked for in order to categorize the comment into one of the motivational mechanisms. I acknowledge that as this analysis was done by myself, there is the possibility of experimenter bias. However, I endeavored to capture the intent behind each comment as impartially as possible.

Autonomy (SDT)/Control (U&G)

Of the responses, 2.9% (2/69) demonstrated an autonomy or control motivational mechanism. These comments indicated that the game gave them the freedom to experiment without penalty and included words and phrases such as "trial and error", "less pressured", "go at your own pace", or otherwise indicated that students felt the game left them feeling that they could experiment without fear of it impacting their grade. Two example comments from participants in the study are as follows:

> *"That there was no penalty for messing up the code. You just kept trying until you got it right."* - P20

> *"I liked that it was optional and it didn't hurt your grade if you didn't work on it. I also liked how it gave you output and you could see what you did wrong and why it worked."* - P62

Competence (SDT)/Challenge (U&G)

Of the responses, 17.4% (12/69) demonstrated a competence or challenge motivational mechanism. These comments indicated that the game provided a challenge and helped them learn the material and included words and phrases such as "unlocking the next level", "challenge", "learn", "required you to think", or otherwise indicated

that students felt the game left them feeling challenged and accomplished for having solved each level. Three example comments from participants in the study are as follows:

> *"I like games in general, figuring out the logic and finishing a level was rewarding"* - P33
>
> *"It was challenging to figure out how to beat each level."* - P44
>
> *"I liked that it didn't give you the answer, no matter what. You had to learn how to do it yourself."* - P52

Competition (U&G)

Of the responses, 8.7% (6/69) demonstrated a competition motivational mechanism in that they expressed that they enjoyed the "competition" or being able to "win", or "defeat" the game and/or their classmates. Two example comments from participants in the study are as follows:

> *"As a very competitive person, RubyWarrior encouraged me to learn quickly and progress, in order to stay competitive with my classmates."* - P34
>
> *"It makes me learn but since I am trying to win a game, I don't notice how much I am learning and studying."* - P22

Fantasy (U&G)

Of the responses, 3.9% (2/69) demonstrated a fantasy motivational mechanism in that they expressed that they enjoyed the role-playing game (RPG) theme or that they liked feeling immersed in the game world:

"I like to feel immersed in a game world where I am constantly being challenged to solve problems with a purpose. In this case, to escape the level and rescue captives." - P5

"Reminds me of old school RPGs." - P17

Interest (U&G)

Of the responses 39.13% (27/69) demonstrated an interest motivational mechanism. These comments indicated that the game was "interesting" and included words such as "fun", "engaging", "interactive" "entertaining", "not boring" and so forth. Three example comments from participants in the study are as follows:

"It made ruby more fun." - P9

"It provided an interesting and entertaining means to aid in learning how to use Ruby" - P13

"It was an interesting an entertaining way to apply my knowledge of Ruby, and assisted me in practicing coding in ruby." - P3

Diversion (U&G)

Of the responses, 4.35% (3/69) demonstrated a diversion motivational mechanism in that they expressed that the game provided a break from typical homework assignments. These comments indicated that the game provided a "change of pace" from the norm in the class and included words such as "different", "unique", "atypical", or otherwise indicated that they provided a "break" from the day to day coursework. Two example comments from participants in the study are as follows:

" It was a good way to get engaged and think about the concepts in a different way." - P23

"It was a little more fun than a typical class period to work on it. The only reason I think it should be included in the course is because it was a nice break from the typical days work." - P21

Relatedness (SDT)/Social Interaction (U&G)

None of the responses demonstrated a relatedness or social interaction motivational mechanism.

In the Spring 2018 semester of the study, I also added an additional survey question for those students who continued past the required level: "Why did you continue past the required levels?".

Twenty-six responses by students who indicated that they went past the required levels aligned well with the motivational mechanisms. Respondents were mainly motivated by the challenge, the competition, or simply because it was fun.

Of the respondents, 34.62% (9/26) demonstrated a competence or challenge motivational mechanism. These comments indicated that the game provided a challenge and helped them learn the material and included words and phrases such as "unlocking the next level", "challenge", "learn", "required you to think", or otherwise indicated that students felt the game left them feeling challenged and accomplished for having solved each level. Two example comments from participants in the study are as follows:

"Each level added a challenge and the challenges were enticing..." - P2

"I...wanted to see how far I could get." - P9

Of the respondents, 19.23% (5/26) demonstrated a competition motivational mechanism in that they expressed that they enjoyed the "competition" or being able to "win", or "defeat" the game and/or their classmates. Two example comments from participants in the study are as follows:

"...I was also motivated to complete it during the semester because there was a leaderboard." - P14

"Thought it was fun and enjoyed the competition." - P8

Of the respondents, 15.94% (11/45) demonstrated an interest motivational mechanism. These comments indicated that the game was "interesting" and included words such as "fun", "engaging", "interactive" "entertaining", "not boring" and so forth. Two example comments from participants in the study are as follows:

"I thought it was fun, and/or was a helpful way to study for the test." - P6

"It was fun. I wanted to learn more Ruby so I could do better in the class." -P16

Finally, 45 students across both semesters of the study responded to the survey question that asked what they did not like about Ruby Warrior. These responses primarily had to do with the lack of compelling graphics or student time constraints.

Of the responses, 20.0% (9/45) comments expressed that they did not like the simple text interface and wished that Ruby Warrior had graphics. An example comment from a participant in the study is as follows:

"I don't mind text-based games, but a graphical version would be better." -P29

Of the responses, 17.8% (8/45) of the comments mentioned that it was time-consuming and time constraints kept them from playing. An example comment from a participant in the study is as follows:

> *"I didn't like how we were expected to do Ruby Warrior outside of class for the most part. I have 4 other classes and I did not have the time to put into it in the subsequent weeks. Overall I think it will benefit a lot of students, but due to time constraints and not having many directions to go off of to help make it easier when you don't have the time I lost interest later on. It was very motivating at first and I tried to make the most of it."* -P23

In the Spring 2018 semester, I added a question that asked why they stopped at the level that they did to see if I could uncover what disincentivized continuing for some students. Time constraints were the main reason students stopped where they did. In fact, 70.3% (26/37) of students said that they stopped because they did not have the time to continue. One of these students wished they could go on and another planned to continue when time allowed. Two example comments from participants in the study are as follows::

> *"I still plan to do epic mode on Spring break, and maybe intermediate some time later."* - P21
>
> *"I did stop because i have so much going on but i wish i could play more."* - P33

Only 8.1% (3/37) of the responses explicitly indicated that they were simply not motivated or interested in playing. Two example comments from participants in the study are as follows:

"I wasn't motivated enough to continue." - P11

"Because I didn't want to play " - P40

4.8.1 Perceptions Discussion

The survey results indicated that 43.69% of the survey participants agreed or strongly agreed that Ruby Warrior motivated them to complete more levels than were required and 46.55% of the survey participants agreed or strongly agreed that Ruby Warrior increased their motivation to play in subsequent weeks. As this number was consistent with the percent of students who actually did complete more than the required levels, the survey respondents were likely to be a representative sample of the students in the class. 55.34% of the survey participants agreed or strongly agreed that Ruby Warrior increased their motivation to learn the topics. These results suggest that while some students may not find a game to be motivating, a non-trivial percent of students expressed that a game will motivate them to engage in extra practice even if it is not required for course credit.

Additionally, 74.67% of the survey participants agreed or strongly agreed that Ruby Warrior was a good addition to the course and 62.14% agreed or strongly agreed that they wished they could have played more games like Ruby Warrior in the course. As such, a non-trivial percent of the students enjoyed the game even if they were not motivated to do more than what was required for course credit.

The qualitative survey questions revealed that motivation for playing and for completing additional levels could be categorized into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory

(U&G) [54] with the majority of them motivated by interest, challenge and competition. Again, as with the previous study, this suggests that the game satisfied basic psychological and emotional needs and, therefore, led to a non-trivial percent of students to continue past the levels required for course credit.

Also, as with the previous study, of these motivations, interest (engagement) and challenge/competence comments were the most prevalent. Again, while I did not examine learning outcomes in this study, challenge, one of the two main elements in flow states along with engagement, was found by Hamari et al. [26] to have a particularly strong correlation to learning outcomes.

Additionally, on the quantitative survey question which asked students whether the leaderboard motivated them to complete more levels than were required, 36.21% of the students who completed this question responded that they agreed or strongly agreed with this statement. Therefore, the leaderboard, in that it allowed competitive students a way to measure their progress against the top scorers, was an additional motivating element for at least some students. Furthermore, some students mentioned the leaderboard in the responses to the qualitative question about what they liked about Ruby Warrior or what motivated them to continue past the required levels.

As such, the survey results indicate that the leaderboard did motivate at least some of the students to go beyond course credit requirements to develop technical skills (R2) in the Ruby programming language, which suggests that pairing a leaderboard with such exercises will incentivize at least some students to practice programming skills beyond what is required for course credit.

4.9 Limitations

This study was wholly focused on student motivation and engagement as leading indicators of learning outcomes and did not attempt to measure gains in learning outcomes for those students who spent additional time in the game. Furthermore, the impact of the leaderboard was measured by survey results rather than a between-subjects comparison. Although the results indicate that the leaderboard had some impact on student motivation to complete more levels in Ruby Warrior, it may have had the opposite effect on students who are averse to competition. Also, as I inserted this one game into a semester-long course, I could not account for how much my results have to do with the novelty of a single gamified intervention.

4.10 Conclusions and Future Work

With regard to my first research question, "Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R1), my results clearly show that in this instance, yes they did. Around 41% percentage of students did go on to complete one or more of the optional levels and did spend additional time and attempts in the game. Furthermore, student survey results indicated that they were motivated to not only complete the optional levels, but also to learn the topic itself. These results are promising, but need further investigation to more deeply understand how and when such games can engage students.

In terms of the time effect, student engagement did drop off sharply after the first week, seeming to support the research that suggests that gamified approaches are more effective in the short-term [40] [43]. However, it was worth keeping the exercise

open for students who wanted to dip back into the game as it did motivated some to continue past the initial week even without the promise of course credit. Also, there were other factors to bear in mind, such as the finite number of levels or the students' perception of what more they could learn from continuing to play.

In future studies, it would be helpful to examine the impact of adding a small amount of course credit for completing at least one additional level in subsequent weeks. The addition of credit would be the 'hook' to entice more students to re-engage in the game, and once they have done so, the challenge may well lead to an even higher percent of students who complete levels beyond what is required for course credit.

While I was only able to gather survey results on my research question "Which game elements (leaderboards, badges etc.) provide incentive for students to go beyond the requirements for course credit to develop technical skills?" (R2) I did discover some survey respondents felt the leaderboard motivated them to go beyond the required levels. In future studies it would be helpful to attempt to isolate the leaderboard effect, perhaps with a between subjects study design and to add a survey question to try to identify students who were competition-averse and, as such, disincentivized by the leaderboard.

Finally, as with the previous study, it is important to note that unlike Schreuders' and Butterfield's [53] study of a gamified cybersecurity module, this intervention required no more grading or instructional load than more traditional class exercises.

CHAPTER 5: IMPROVING ENGAGEMENT IN NON-TECHNICAL SKILLS WITH GAMIFICATION

Communication, collaboration and time management are identified as some of the most critical non-technical skills for IT-related career success. Communication is essential for technical personnel as they are often called upon to explain technical details to non-technical managers and other stakeholders. Additionally, as today's technical projects are often broad in scope and require large teams to implement and deploy, the ability to collaborate effectively in teams is a key skill employers seek in graduates. Finally, good time management skills are instrumental in preventing the high costs of missed deliverable deadlines in technical fields. Non-technical skills, though essential to success in IT professions, are not typically primary learning objectives for computing programs as computer science curricula are already crammed with technical learning objectives. As such, in this study, I investigate whether a gamification intervention would provide incentive for students to practice collaboration, communication and time management skills.

This chapter depicts the first semester of a two-semester study that I conducted to compare gamified and non-gamified approaches to classroom behavior management as vehicles for providing incentive for students to develop the aforementioned non-technical skills essential to the discipline (R3) (see Section 1.4). The study took place over the Fall 2017 and Spring 2018 semesters in four face-to-face sections and two

online sections of my university's Introduction to Operating Systems and Networking class.

In Fall 2017, I gathered data on the impact of the gamified intervention on student motivation to engage in the non-technical skills of collaboration, communication and time management. In Spring 2018, I gathered comparison data on the impact of participation points without any gamification on the same non-technical skills.

5.1 Setting

The setting for this study is the same as the study depicted in Chapter 3. As a reminder, the Introduction to Operating Systems and Networking class at UNCC is a large, multi-section junior-level class at the University of North Carolina at Charlotte. See Appendix G for course information. As this course is required of all Bachelor of Science in Computer Science students at the University of North Carolina at Charlotte and as the students in the course are nearing graduation, it seemed an appropriate place in the curricula to incorporate an emphasis on non-technical skills. All three sections of the course completed the same course content and activities, available to students in the Learning Management Systems, Canvas.

The same three instructors taught the course in both semesters of the study. The online section, which was taught by me, was asynchronous and, as such, students mainly worked independently on the course materials. The other two sections of the course were taught by two other instructors in a face-to-face format. In these classes, instructors used the active learning, flipped-class format where students were required to complete preparatory activities before class, such as watching videos and/or reading

articles and the textbook. Class time was spent completing learning activities in light-weight teams.

As a survey done for another study in this class in the Spring 2017 semester indicated that a 93.1% of students played at least some games in their leisure time (see Table 5 in Chapter 3), I wanted to see whether gamifying an entire course would motivate students to engage in co-curricular activities designed to encourage them to develop non-technical skills in collaboration, communication, and time management.

While there are numerous ways to measure collaboration, communication and time-management, in this study, I used data on forum for the online section and in-class participation for the face-to-face sections as well as system interactions in the gamification platform (more on that below) as measures of communication and collaboration. With regard to time management, I looked at early and missing assignment submissions as an indicator that students were managing their time well.

In past semesters, course instructors involved in the study have penalized late work, and/or used an engagement score to reward collaboration and communication. However, students continued to struggle with these skills.

In the hopes that it would incentivize students to develop these essential skills, I decided to employ a fantasy-themed, gamified classroom behavior-management tool called Classcraft [6]. The mission of the company Classcraft is to provide a game framework that allows teachers in the K-12 classroom to improve educational outcomes with fun and play. I assess the effectiveness of this tool in large undergraduate classes.

5.2 Gamification Platform

Topîrceanu [57] demonstrated that gamified undergraduate Algorithm Design and Analysis and Computer Organization classes had higher attendance, homework and quiz completion than non-gamified classes. In fact, 50% of all students in the gamified group had perfect attendance versus 9% in the control group demonstrating that gamification can motivate students to attend class. However, each of these classes were small, with between 17 and 52 students in them, compared to some of the sections used for my study. Also, as the gamified solution in the Topîrceanu study was implemented for face-to-face classes, I wanted to see whether a gamified solution intended for face-to-face grades K-12 classes would scale to much larger classes and whether it could be repurposed to motivate online students to participate more actively.

The Classcraft gamification platform was applied to the three sections of the class for the entire Fall 2017 semester. This gamified semester of the study will be compared with a non-gamified implementation of participation points in the next chapter of this dissertation.

In Classcraft, students play in teams to earn or lose points for in-class behaviors and, as they gain points, unlock real-life classroom privileges, called powers in Classcraft. The specific behaviors and powers are customizable by course instructors and can be decoupled completely from the course content. At the time that I designed the study, Classcraft was intended to be used to promote classroom behaviors and did not include a robust system for incorporating course content into the tool. In essence, the platform was **designed to be used in parallel with instructors' existing**

course materials and lessons. A quest system has since been introduced which would allow some or all course content to be integrated into the platform.

For this study, however, the platform was configured to run in parallel with the existing course content in Canvas in order to promote the development of the aforementioned set of non-technical skills. Due to the different delivery methods for the course, the configuration had to be slightly different for the online section and face-to-face sections. As such, the other two instructors helped with the tool configuration for their face-to-face sections. See the *Introduce Classcraft to your Students* video [7] to gain a better understanding of how Classcraft works in general.

In our implementation of Classcraft, students worked with their teams to gain experience points (XP) or gold pieces (GP) for behaviors that demonstrated collaboration, communication and good time management or lost health points (HP) for behaviors that did not demonstrate such behaviors. For example, students could earn 40 XP for asking a good question on the course discussion forum or in class and could earn 75 XP for helping another student understand a course concept. They could also lose 15 HP for being rude or disrespectful to another student. Gold pieces could be likewise earned for such things as being the first person to turn in all assigned work in a given week or as a result of training pets in the platform. See appendix D for a full list of behaviors.

Students in Classcraft choose to play as one of three character classes: mage, healer or warrior. As students earn experience points (XP) in the game, they level up their character or avatar. With each new level, students gain 1 power point (PP) that can be spent on learning powers specific to their character class. These powers can

impact individual students or the entire team by providing such in-class perks as short deadline extensions, bonus points on a test, and extra time on a test. For example, in our implementation of Classcraft, mages and healers could work up to granting their entire team 2 bonus points on a test and warriors could learn a power that gave them 2 bonus points on a test. See appendix D for a full list of powers.

Figure 11: Classcraft Character with Pets

Power choices are constrained according to each character classes' power tree. See figure 12 for an image of the power tree of a student who was a level 14 mage by the end of the semester. Powers in the first row each cost 1 power point (PP), powers in the second row cost 2 PP and powers in the third row cost 3 PP each. The arrows indicate the required progression. For example, for the student to have earned the Clairvoyance power, they had to work down the tree from Mana Transfer to Mana Shield in the first column and then had to work down the tree from Time Travel to Cheat Death and, finally, to Clairvoyance in the second row. This would have cost them 9 power points in total and, as such, they would have to have leveled up 9 times.

As mentioned, powers could be used for real-world benefit. Collaborative powers

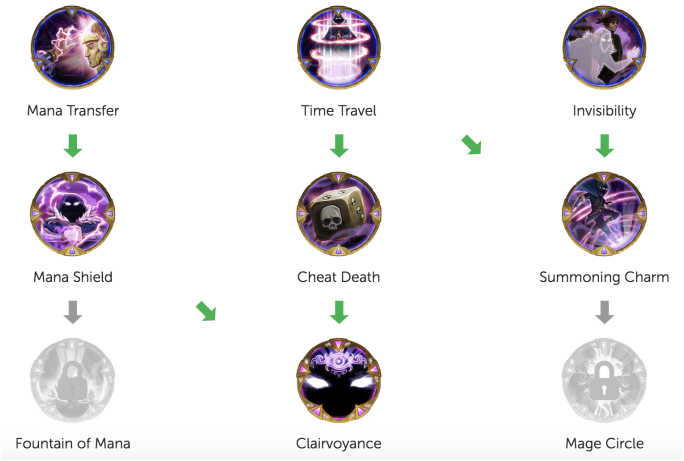


Figure 12: Level 14 Mage Power Tree

that benefit the entire team earn XP to help a student level up more quickly and so the platform encourages collaboration within each team. After learning powers, students can then use them by spending action points (AP), which regenerate a little each day. The cost of each power was configured by the course instructors. See appendix D.

Some powers could be used directly by students in the tool without instructor intervention. For example, a student with a mage character class could use a power called Fountain of Mana where they could replenish all of a teammate's AP. This could, for instance, enable a teammate with a healer character class to use this AP on a power called Prayer, which would give all teammates two bonus points on a test.

There were also powers where instructors had to deduct the AP manually from Classcraft and apply the perk to the student and/or team. As Classcraft was designed for smaller K-12 classrooms, there had to be a way to manage requests of this nature for large college classes. As such, I created a Google form for each instructor for power requests and each instructor shared a link to it with their students. This design by

its nature promoted time management as students had to submit these requests by certain deadlines.

The powers themselves often required students to use one or more of the non-technical skills. For example, in the aforementioned Prayer example, the student had to manage their time well so as to have accumulated enough AP for the power and had to remember to use it and to make the request for the bonus points during the week of the test. Alternatively, the healer student had to collaborate with a mage on their team, who had to manage their time well so as to have accumulated enough AP to use Fountain of Mana during the week of the test and the healer student would, again, have to remember to make the request during the week of the test. Instructors, upon receipt of the request to use Prayer, would verify that the healer had enough Action Points (AP), would deduct the AP in Classcraft and would apply the perk to the entire team by giving them all their two points on the test.

Students can also earn gold pieces (GP), however unlike the benefits gained through earning XP, GP does not lead to any real world benefit. GP does allow students to buy armor to customize their avatars, and as will be shown in the results, students were motivated to do so.

Health point (HP) losses were factored into an engagement score along with XP and so had real world consequences. Additionally, there were both in-game and real-world consequences for running out of health completely as students who "fall in battle" are required to complete a "sentence" such as attending a counseling session with the teaching assistants or course instructor before they are able to earn points or use powers again. See appendix D for sentences.

The face-to-face sections calculated a student engagement score, which was worth 10% of the final course grade, using Classcraft performance and class attendance. For the online section, engagement was calculated from Classcraft performance alone.

5.2.1 Procedures

Students were introduced to Classcraft during the first week of class with the Classcraft student information resource in appendix C. They then completed a short introductory survey which asked for their thoughts on Classcraft and their top two choices for a character class (see below) to help divide them into teams.

The students were then evenly distributed according to their response to the question "What do you think of Classcraft after reading about it and watching the introductory video?". The goal was to ensure that students who were enthusiastic about the game be grouped with students who were less enthusiastic about it and to evenly distribute the character classes across the teams.

In Classcraft, much like massive multi-player online role playing game such as Blizzard's World of Warcraft [3], students create a virtual avatar and choose a character class (warrior, healer, or mage). See figure 13.

As each character class was configured with different powers, teams had to be balanced such that each had at least one of each class (mage, warrior and healer). The instructors arranged teams to ensure students could play as either their first or second choice of character classes.

In contrast with World of Warcraft, rather than interacting with one another in a 3D environment, students interacted with one another and their instructor in the

(a) Female Owl Warrior (b) Male Wanderer Healer (c) Female Water Mage

Figure 13: Classcraft Classes

real world, or, in the case of the online section, in the Learning Management System.

In the online course, top XP earners were announced along with the behaviors these students exhibited to help them succeed in each week of the course. In the face-to-face sections, while the top scorers were not highlighted in any way, students could see the standing of their team compared to other teams as well as their individual standing compared to their teammates and the class as a whole from within the Classcraft platform. As such, students who were interested in a competitive element could easily check on their standing relative to their classmates.

At the end of the semester, after grades were posted, I sent a recruitment email for students to complete a brief online survey about their Classcraft experiences to the face-to-face classes and I had another professor send a recruitment email to my online class. Students were required to consent to participate in the survey.

Anonymized Classcraft data were collected from the Classcraft app. Data analysis provided information about game level, XP, GP gained and HP lost for which be-

haviors, AP spent for which power, and other interactions such as training pets and buying armor. Additionally, data were collected from the Canvas Learning Management System on assignment punctuality for all three sections and forum data were collected and coded for the online class. The data also included student perceptions of the game and engagement in the course using the Student Course Engagement Questionnaire (SCEQ) proposed by Handelsman et al. [27]. See appendix E for the survey. My study methods and data collection were approved by the University of North Carolina at Charlotte's Institutional Review Board (IRB Number: 17-0320). See appendix I.

5.3 Participants

Study participants were students in the three sections of the Fall 2017 course.

In this semester of the study, 233 computer science majors aged 18-45 ($\mu = 22.62$, $\sigma = 3.37$) participated in the gamified condition of the study. The age distribution is depicted in Table 40. Among the participants, 199 (85.4%) were male and 30 (12.88%) were female. The grade point average (GPA) of the participants ranged from 2.042 to 4.0 ($\mu = 3.12$, $\sigma = 0.50$). The race/ethnicity demographics of the participants are shown in Table 41.

Table 40: Fall 2017 Classcraft Age Distribution

Age	**# Participants**	**% Participants**
18 - 24	189	81.12%
25 - 34	38	16.3%
35 - 45	2	0.86%
Not Specified	4	1.72%

With respect to game playing behaviors, of 27 survey respondents who responded

Table 41: Fall 2017 Classcraft Race/Ethnicity Demographics

Race/Ethnicity	# Participants	% Participants
African American	28	12.02%
Any 2 or More Races	13	5.58%
Asian or Pacific Islander	31	13.30%
Caucasian	127	54.51%
Hispanic	17	7.30%
International	9	3.86%
Not Specified	8	3.43%

to the question, 5 (18.52%) reported that they did not play recreational computer or mobile games, 9 (33.33%) reported that they played more than 0 but less than 3 hours per week, 5 (18.51%) reported that they played 3 to 7 hours per week, and 8 (29.63%) reported that they played more than 7 hours per week. See Table 42. These survey respondents spent far less time playing board games each week, with 22 (81.48%) reporting that they did not play them, 4 (14.82%) reporting that they played more than 0 but less than 3 hours per week, 1 (3.70%) reporting that they played 3 to 7 hours per week, and 0 (0.0%) reporting that they played more than 7 hours per week. See Table 13. However, as the response rate was so low, the survey respondents may not be a representative sample of the larger pool of study participants.

Table 42: Fall 2017 Classcraft Game Playing Behaviors of Respondents

Hours/Week Playing	Digital Games	Board Games
None	5 (18.52%)	22 (81.48%)
Greater than 0 but less than 3	9 (33.33%)	4 (14.82%)
Between 3 and 7	5 (18.51%)	1 (3.70%)
Greater than 7	8 (29.63%)	0 (0.0%)

5.4 Results

5.4.1 System Interactions

As mentioned earlier, Classcraft was implemented in parallel with the Canvas course content. Students could receive XP in Classcraft without logging into the system for in-class and Canvas behaviors. However, they needed to log into the Classcraft system to learn new powers, train pets, and to use their powers.

The percentage of students interacting with the tool increased as students learned how to use it. Only 7.3% of students were interacting in the Classcraft platform in August. By September, this had increased to 57.3% of students, in October, 78.9% of students were interacting in the Classcraft system and in November, 83.6%. Participation trailed off in December to 65.1% of students during the exam period. See table 43 and figure 14.

Table 43: Monthly System Interactions per Student

	% Students	**Pets Trained**	**Pwrs Used**	**Pwrs Learned**	**Total # Interactions**	**Average # Interactions**
Aug	7.3%	21	12	2	35	2.06
Sep	57.3%	484	183	60	727	5.47
Oct	78.9%	697	458	298	1453	7.94
Nov	83.6%	602	461	248	1311	6.76
Dec	65.1%	188	289	103	580	3.84

Likewise, the total number of system interactions and the average number of system interactions per student increased from 35 and 2.06 respectively in August to 1453 and 7.94 respectively in October. Both of these metrics trailed off a little in November to 1311 and 6.76 respectively and then decreased to 580 and 3.84 respectively in December during the exam period. See table 43 and figure 15.

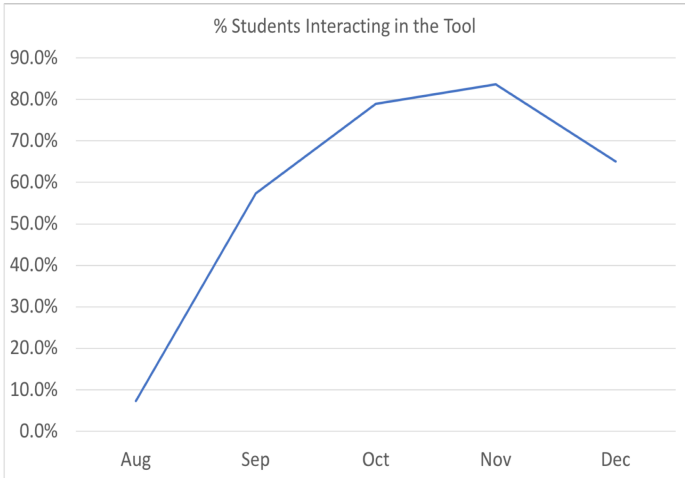


Figure 14: Monthly System Interactions by % of Students

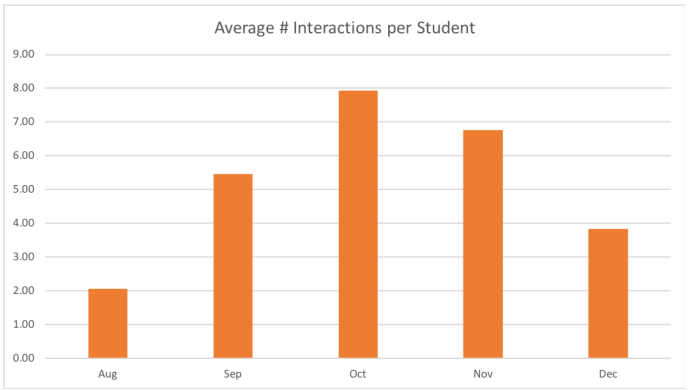


Figure 15: Monthly Average System Interactions by Student

Powers had an indirect impact on the course grade as they could be used to mitigate damage (loss of health points) for late work or other behaviors and could be used for extra time on an assignment or bonus points on the tests. Pets, on the other hand, had no impact on the course grade either directly or indirectly but there were a variety that could be collected by students. These pets, once purchased with gold pieces, could be sent on training missions to gather gold pieces (GP) which could, in turn, be spent on avatar customization. For all months except December, the number of system interactions that involved pets were higher than either of the powers used or powers learned interaction types and in August and September, the number of system interactions that involved pets were higher than a sum of the powers used and the powers learned system interaction types. See table 43 and figure 16.

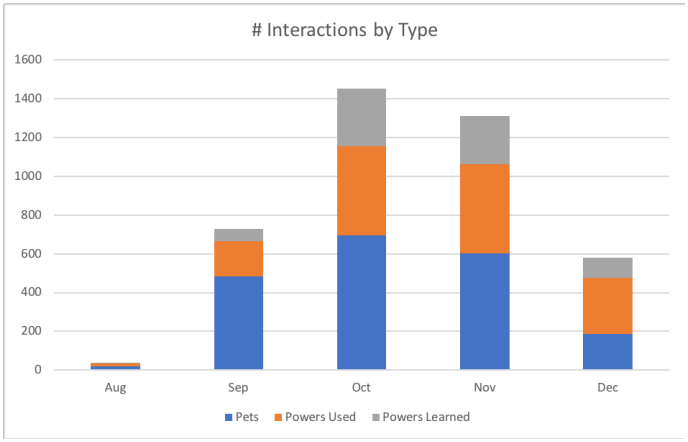


Figure 16: Monthly System Interactions by Type

Students activity by week fluctuated more than revealed by the monthly data but tended to trend upwards until peaking in week 12. See table 44 and figure 17.

Table 44: Weekly System Interactions by Type

Week	Pets Trained	Powers Used	Powers Learned	Total Interactions
1	21	12	2	35
2	87	24	4	115
3	131	47	6	184
4	126	46	14	186
5	140	66	36	242
6	140	64	27	231
7	114	64	68	246
8	141	78	55	274
9	145	137	77	359
10	157	115	71	343
11	144	111	45	300
12	173	126	62	361
13	133	97	84	314
14	152	127	57	336
15	118	140	41	299
16	70	149	62	281

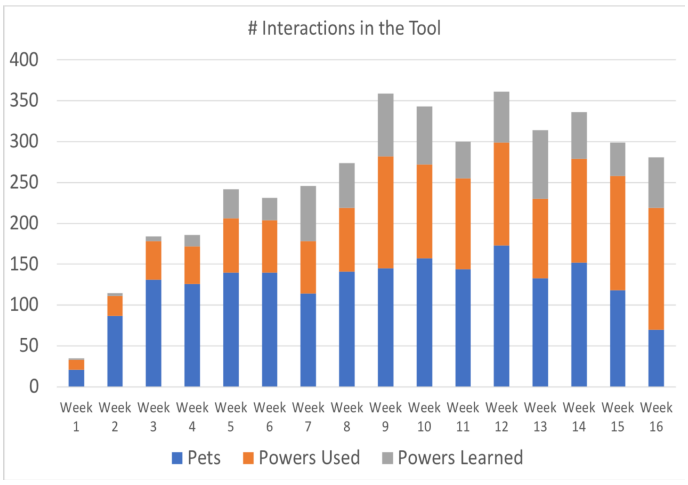


Figure 17: Weekly System Interactions by Type

5.4.2 Time Management

Students were rewarded with experience points (XP) for turning in work ahead of deadlines. In the case of the face-to-face sections, students were rewarded for submitting their work before the end of class so as to encourage them to make good use of class time. In the case of the online section, students were rewarded if they turned in all work for a particular week at least 24 hours before the deadline. Missing work was also penalized with health point (HP) deductions.

5.4.2.1 Early Submissions

In the first face-to-face section (F2F1), the instructor began awarding XP for early submissions on 20-Sep. Between 50% and 100% of students turned in at least one exercise during class time and received XP for doing so. Beginning with 28-Sep over 77.8% of students consistently turned in at least some of their assigned work during class time. However, the number of students who turned in all exercises during class time varied a great deal throughout the semester. See table 45 and figure 18.

Table 45: Students Who Completed In-Class Exercises During Class - F2F1

Date	**# Some**	**% Some**	**# All**	**% All**
20-Sep	99	91.67%	7	6.48%
21-Sep	54	50.00%	24	22.22%
28-Sep	107	99.07%	90	83.33%
2-Oct	93	86.11%	93	86.11%
12-Oct	107	99.07%	65	60.19%
21-Oct	106	98.15	106	98.15%
23-Oct	94	87.04	94	87.04%
31-Oct	84	77.78%	84	77.78%
20-Nov	108	100.00%	33	30.56%
3-Dec	101	93.52%	42	38.89%
9-Dec	104	96.30%	90	83.33%

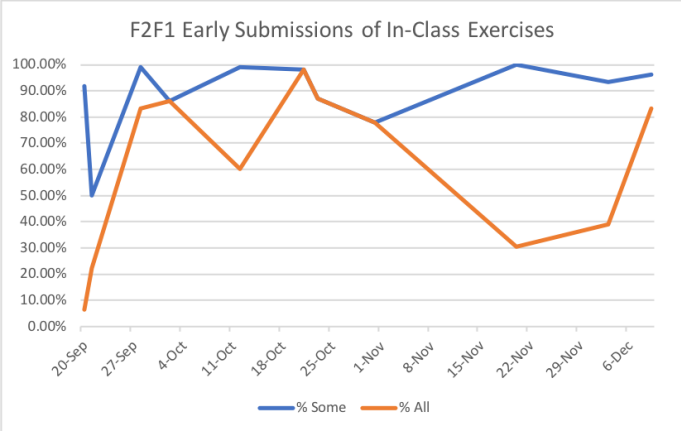


Figure 18: Students Who Completed In-Class Exercises During Class - F2F1

In the second face-to-face section (F2F2), the instructor began awarding XP for early submissions on 24-Oct. Between 10.71% and 85.71% of students turned in at least one exercise during class time and received XP for doing so. Both the number of students who turned in some exercises during class time and those who turned in all exercises during class time varied a great deal throughout the semester. See table 46 and figure 19.

Table 46: Students Who Completed In-Class Exercises During Class - F2F2

Date	**# Some**	**% Some**	**# All**	**% All**
24-Oct	7	12.50%	7	12.50%
3-Nov	36	64.29%	4	7.14%
7-Nov	42	75.00%	13	23.21%
8-Nov	36	64.29%	21	37.50%
15-Nov	31	55.36%	48	85.71%
16-Nov	48	85.71%	8	14.29%
18-Nov	6	10.71%	6	10.71%
19-Nov	39	69.64%	5	8.93%
20-Nov	46	82.14%	28	50.00%
8-Dec	43	76.79%	18	32.14%

On average, in the F2F1 section, 61.28% of students turned in all activities for a given week early versus 28.21% in the F2F2 section. These early submissions were

higher on average in the F2F1 class where the instructor rewarded students for them earlier in the semester and more frequently during the first half of the semester.

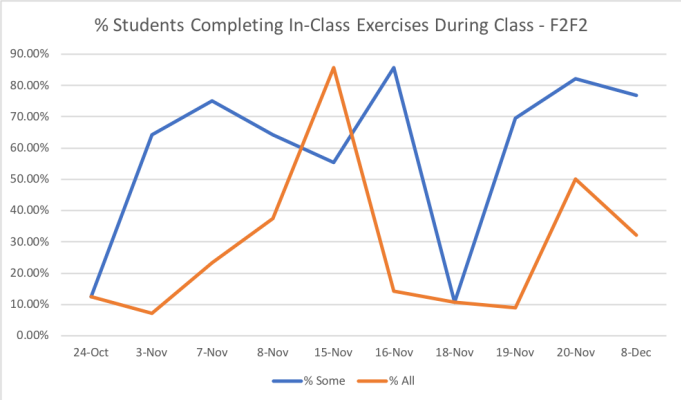


Figure 19: Students Who Completed In-Class Exercises During Class - F2F2

In the online section between 5.19% and 44.16% of students turned in their assigned exercises at least a day earlier than they were due in a given week. As with the face-to-face sections, the number of students who submitted their work early varied a great deal over the semester. See table 47 and figure 20.

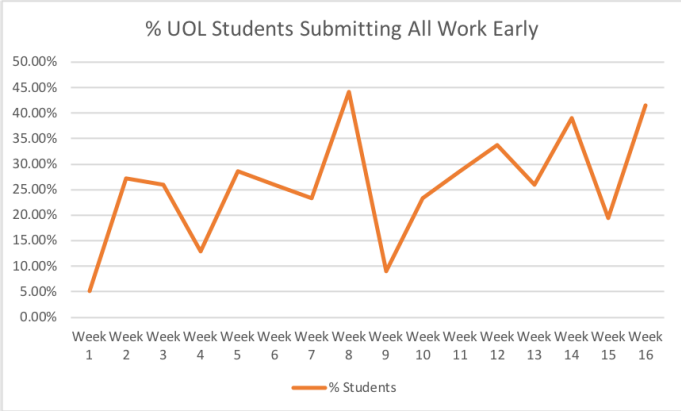


Figure 20: UOL % Students who Submitted all Assigned Work Early

5.4.2.2 Missing Submissions

As mentioned earlier, students were supposed to receive a health point (HP) deduction for failing to turn in assigned work in the online section. However, according

Table 47: Fall 2017 UOL Early Submissions by Week

Week	# Students	% Students
1	4	5.19%
2	21	27.27%
3	20	25.97%
4	10	12.99%
5	22	28.57%
6	20	25.97%
7	18	23.38%
8	34	44.16%
9	7	9.09%
10	18	23.38%
11	22	28.57%
12	26	33.77%
13	20	25.97%
14	30	38.96%
15	15	19.48%
16	32	41.56%

to the logs, there were no such penalties administered by the instructors of the face-to-face sections.

In the two face-to-face sections, when compared with a previous, non-incentivized semester, about the same percent of students turned in every assignment - 52.902% in the Fall 2017 Classcraft semester versus 51.38% in the non-incentivized course. Also, roughly the same percent of students failed to turn in more than 5 assignments - 11.61% in the Fall 2017 Classcraft semester versus 11.93% in the Spring 2017 non-incentivized semester. See table 48.

However, in the online section where there was a weekly health point (HP) penalty assessed for missing assignments, a higher percent of students turned in every assignment when compared with the previous, non-incentivized semester - 70.51% in the Fall 2017 Classcraft semester versus 51.90% in the Spring 2017 non-incentivized

Table 48: F2F Missing Assignments by Semester

# Missing Assignmts	Non-Incentivized Semester		Gamified Semester	
	# Students	% Students	# Students	% Students
none	56	51.38%	82	52.90%
1	16	14.68%	24	15.48%
2	9	8.26%	15	9.68%
3	9	8.26%	15	9.68%
4	6	5.50%	1	0.65%
5 or more	13	11.93%	18	11.61%

semester. Also, a lower percent of students failed to turn in more than 5 assignments - 6.41% in the Fall 2017 Classcraft semester versus 15.19% in the Spring 2017 non-incentivized semester. See table 49.

Table 49: UOL Missing Assignments by Semester

# Missing Assignments	Non-Incentivized Semester		Gamified Semester	
	# Students	% Students	# Students	% Students
None	41	51.90%	55	70.51%
1	14	17.72%	12	15.38%
2	6	7.59%	1	1.28%
3	4	5.06%	2	2.56%
4	2	2.53%	3	3.85%
5 or more	12	15.19%	5	6.41%

5.4.3 Collaboration and Communication

5.4.3.1 Collaborative versus Individual Powers

As mentioned earlier, students must spend action points (AP) to use powers that will give them certain perks or benefits in class. Powers can either be collaborative or non-collaborative (individual), where the former can be used to help a teammate or the entire team and the latter only benefit the individual using the power. Classcraft motivates students to use their action points on collaborative powers to benefit others by granting a certain amount of experience points (XP) each time a student uses a

collaborative power.

In the two face-to-face sections, students used more individual powers than collaborative powers. In the first face-to-face class (F2F1), 35.60% of all powers used were collaborative, whereas 64.40% were individual and in the second face-to-face class (F2F2), 44.58% of all powers used were collaborative, whereas 55.42% were individual.

However, in the online section (UOL), where student interaction took place on Canvas discussion forums, students used a higher percent of collaborative powers. In fact, 73.26% of all powers used were collaborative, whereas only 26.74% were individual. See table 50. As explained below, this may be attributed to a dedicated forum provided to the online students for team strategizing whereas there was no such dedicated forum for the face-to-face students to strategize as a team nor was class time set aside for this purpose.

Table 50: Collaborative versus Individual Power Usage

Power Type	**UOL # Uses**	**UOL % Uses**	**F2F1 # Uses**	**F2F1 % Uses**	**F2F2 # Uses**	**F2F2 % Uses**
Individual	146	26.74%	398	64.40%	138	55.42%
Collaborative	400	73.26%	220	35.60%	111	44.58%

Teams in the face-to-face sections could strategize as a team at any point during class time and instructors largely left the teams to do so at their discretion. The online section, on the other hand, was provided with a weekly forum specifically for the purpose of strategizing about how to help one another and were required to post at least one time per week on this team forum in order to unlock the week's lesson. Also, I announced in week 5 that entire teams could earn XP bonuses for "demonstrating

awesome team collaboration" for making good strategic use of this discussion forum. Teams achieved this bonus by strategizing about how to use their powers to benefit the team as a whole.

An example post from a student in week 9 in a team that earned this bonus is as follows: *"I just learned sainthood which allows me to extend the deadline of an assignment by 1 hour. At first I thought this might not be very useful but it looks like we have a lot of assignments this week. So I will go ahead and try to extend our last assignment by an hour (Exercise 9-2-2)."*

Teams that earned the bonus two weeks in a row would get to choose a team name in addition to earning the additional XP. There was at least one team who earned this bonus in each week from week 5 until the final week when such points were awarded. In weeks 6, 9, 13 and 14, four of the eighteen teams (22.22%) earned bonus points for team collaboration on this team forum. See table 51.

Table 51: UOL Bonus Points Earned for Team Collaboration

Week	**# Students**	**# Teams**
5	10	2
6	25	4
7	15	3
8	5	1
9	20	4
10	4	1
11	4	1
12	9	2
13	19	4
14	19	4

5.4.3.2 Forum Posts

In Barata et al.'s [1] five year study of how gamification can improve engagement, the authors conclude that increased forum participation seem to reflect a deeper level of engagement. As such, I analyzed forum participation data as a leading indicator of engagement in the online class as this section of the course was provided with a weekly Q&A forum where they could ask questions or respond to classmates' questions.

As a baseline, I will compare the gamified Classcraft semester with an earlier semester of the same online course, also taught by me, in which there was no incentive provided for forum participation aside from encouraging students to use the forum before reaching out to the instructor or TAs. In the gamified Classcraft semester, on the other hand, students were rewarded with XP for asking questions, responding to other students, and for providing helpful resources or identifying course content issues.

When compared with the section of the course that provided no incentives for forum participation, the gamified section in the Fall 2017 showed significant gains in both the number of posts on the forum and in the average number of posts per student. In the Classcraft semester, 97.3% of the students participated at least one time in the forums compared to 53.6% in the non-incentivized semester, a gain of 43.7%. Furthermore, the average number of posts per student were roughly 4 times greater in the gamified class as in the non-incentivized one. See table 52. I will compare these to an incentived, participation points semester in the next chapter of this dissertation.

Table 52: Gamified versus No Incentive Forum Activity

	# Students in Class	# Posted	% Posted	# Posts	Avg Posts /Student
Gamified	74	72	97.30%	892	12.4
No Incentives	56	30	53.57%	122	4.1

5.4.3.3 In-Class Participation

The face-to-face sections rewarded students with experience points (XP) for participating in class by asking and answering questions, making suggestions, identifying a mistake or issue with the course content, showing good team collaboration and so forth. The teaching assistants captured this information and the instructors later input it into Classcraft.

In the first face-to-face section (F2F1), the instructor captured participation 12 times over the course of the semester - 7 times in September, 3 times in October and 2 times in November. In those weeks, between 1.85% and 35.19% were awarded XP for class participation. See table 53.

Table 53: F2F1 Class Participation with Classcraft

Date	# Students	% Students
1-Sep	3	2.78%
5-Sep	2	1.85%
8-Sep	6	5.56%
12-Sep	2	1.85%
19-Sep	12	11.11%
25-Sep	1	0.93%
28-Sep	1	0.93%
6-Oct	18	16.67%
21-Oct	34	31.48%
31-Oct	38	35.19%
8-Nov	3	2.78%
30-Nov	9	8.33%

In the second face-to-face section (F2F2), the instructor also captured participation 12 times over the course of the semester - 5 times in September, 4 times in October, and 3 times in November. In those weeks, between 1.85% and 35.19% were awarded XP for class participation. See table 54.

Table 54: F2F2 Class Participation with Classcraft

Date	# Students	% Students
6-Sep	1	1.79%
18-Sep	4	7.14%
19-Sep	2	3.57%
25-Sep	2	3.57%
27-Sep	6	10.71%
4-Oct	2	3.57%
11-Oct	4	7.14%
16-Oct	5	8.93%
23-Oct	4	7.14%
13-Nov	4	7.14%
15-Nov	4	7.14%
20-Nov	5	8.93%

Due to the burdens of implementing Classcraft on such large classes, instructors did not always have the time or teaching assistant resources to award participation and when they did there was, at times, a long delay between when the participation XP was earned and when it could be logged to Classcraft, which is evident in the decreasing times per month when participation XP was awarded. However, there was no correlation found between this and the number of students participating in each section, which varied a great deal for both sections over the semester.

5.5 Instructor Perceptions

In general the instructors felt gamification has the potential to motivate students to engage in non-technical skills, but that there would need to be some adjustments

and fine-tuning to make it scalable for large college classes.

The F2F1 instructor noted the following about Classcraft:

> *"...several students had trouble navigating Classcraft and understanding how it works."*
>
> *"Students had to submit 15 minutes after class time to get engagement points, so multiple students complained that they needed more time to understand the exercises/assignments and hence could not earn any Classcraft XP."*
>
> *"Lots of Mages complained about how Classcraft was unfair to their character class. This caused confusion and required me to go in and reset powers for several students."*

The F2F1 instructor also found that the lack of teaching assistant accounts or import capabilities was a severe limitation in large-scale college classes as she had to manually record everything one student at a time within the tool.

The F2F2 instructor noted the following about the Fall 2017 gamified semester:

> *"...there seemed to be a noticeable interest in completing work early at a point in the semester. I think this coincided with a week when I posted a big batch of XP and a considerable number of students leveled up due to this. Once students leveled up, they started noticing that available Classcraft powers could have an impact on their grade."*
>
> *"I also noticed an uptick in interest after the first exam. The class as a whole did not do great and it is my impression that one of the ways they thought they could improve their grade was by earning more XP, leveling up and using powers to earn bonus points."*
>
> *"I think that some students either did not get what Classcraft was or simply did not care to participate. Even though I tried to setup my grading distribution in a way that prevented a negative impact on their grade, I worry that they still were affected. The number of students was very small though."*
>
> *"I am a firm believer in the importance of promoting engagement and the development of non-technical skills. I think that anything we can do to encourage students to work beyond the bare minimum is worth considering. I think that*

implementing Classcraft may not have been perfect, but it was a positive step in this direction."

As I taught the online section, I will also include my perceptions here with the caveat that these were just observations based on my own personal experiences as the instructor rather than as a researcher.

In the Fall 2017 gamified semester I note the following:

There was definitely more collaboration and communication among students in the forums than I had observed in past semesters.

While a few students expressed to me that they did not like Classcraft, many sought me out to say that they thought the concept was novel and fun.

Scalability was definitely a challenge with a large class but I liked that it pushed me to continually interact with my online students. I felt this allowed me to personally and more regularly engage with them as teaching assistants were responsible for grading coursework.

I am concerned about the few students who expressed that they did not like Classcraft as it may have led to decreased motivation in the coursen for them.

5.6 Student Perceptions

Student perceptions of the Classcraft were captured in a survey at the end of the semester after grades had been posted. As I wanted to be sure that students felt they could be honest with their feedback, I had one of the other instructors send the recruiting email to my students and I sent the recruiting email to their classes. The survey was completed by 41 students regarding their perceptions of Classcraft and their engagement in the course, a response rate of 17.6%.

The first section the survey were based on Handelsman et al.'s Student Course Engagement Questionnaire (SCEQ) [27] in order to capture the engagement behaviors and attitudes of students toward the course so I would be able to compare student engagement in this gamified semester with the second semester of the study, which would use participation points. These responses are presented in full in Chapter

6. The rest of the survey included demographic questions and specific questions on Classcraft. See appendix E for the complete survey.

The survey question which asked what students liked about Classcraft generated 18 comments. What follows is a categorization of those 18 student comments into the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54]. For each category, I explain the words and phrases that I looked for in order to categorize the comment into one of the motivational mechanisms. I acknowledge that as this analysis was done by myself, there is the possibility of experimenter bias. However, I endeavored to capture the intent behind each comment as impartially as possible.

Autonomy (SDT)/Control (U&G)

Of the responses, 72.2% (13/18) demonstrated an autonomy or control motivational mechanism. These comments indicated that the game gave them some control over the course and that earning points and leveling up could help them in the class somehow and include words such as "control" or phrases that indicated that students felt the game left them feeling that it empowered them in the class. Two example comments from participants in the study are as follows:

> *"I like that the powers of the class gave you some degree of control in the course. Such as turning in assignments late and being able to negate the penalty, or accruing bonus points for tests..."* - P15

> *"...I also liked the fact that earning points could level you up and potentially help you and others in class (on assignments, tests, etc.)"* - P18

Competence (SDT)/Challenge (U&G)

Of the responses, 22.2% (4/18) demonstrated a competence or challenge motivational mechanism. These comments indicated that the game provided a challenge and helped motivate them to do better in the class and included words and phrases such as "advance in the game", "incentive", "advance in the game", "go above and beyond",

or otherwise indicated that students felt the game left them feeling challenged. Two example comments from participants in the study are as follows::

> *"I like that Classcraft motivated me to be a better student. Since it was like a game, I had reason to want to participate more and advance in the game."* - P11

> *"Motivation to go above and beyond "* - P5

Interest (U&G)

One of the responses demonstrated an interest motivational mechanism in that it expressed that Classcraft was "entertaining":

> *"It is an excellent activity that engages the students and helps make the learning process more entertaining."* - P1

Competition (U&G)

One of the responses demonstrated a competition motivational mechanism in that they expressed that the platform provided a "ranking system" that allowed the student to compare themselves against the rest of the class: *"I enjoyed the fact that you could see your xp compared to all other students; in a way, it felt like a ranking system in the class, which made me more inclined to participate."* - P18

Relatedness (SDT)/Social Interaction (U&G)

One of the responses demonstrated a relatedness or social interaction motivational mechanism because it referenced that the platform motivated students to engage more in communicating on the forums: *"It also gets students talking more in forums because of the XP bonus they receive."* - P19

Diversion (U&G)

None of the responses demonstrated a diversion motivational mechanism.

Fantasy (U&G)

None of the responses demonstrated a fantasy motivational mechanism.

The survey question which asked what students did not like about Classcraft generated 22 responses.

Game Balancing & Mechanics

Of the responses, 36.4% (8/22) of the comments had to do with game balancing and mechanics. Two example comments from participants in the study are as follows:

> *"The classes were unfair. Mages were super underpowered the until about a month left in class when they too could earn extra points on tests."* - P9

> *"I didn't like the process of unlocking a tier 3 power; in order to do so you would first have to unlock two tier 2 powers, instead of just unlocking the tier 2 power that was pointing to the tier 3 power."* - P10

Time & Effort

Of the responses, 27.3% (6/22) of the comments had to do with the time and effort as well as the learning curve required to engage with Classcraft. Two example comments from participants in the study are as follows:

> *"We could have used the time and energy from that towards the actual coursework."* - P13

> *"The time required to learn the system, time wasted."* - P18

Finally, one of the students mentioned in a course evaluation at the end of the semester that they felt gamification was not appropriate for a college setting and instructors received a few similar comments on their student course evaluations:

> *"Honestly I dont think its the right choice for a college setting. To me it was really annoying to play a game for class and often felt childish. I feel like in college people are going to do their work or not, this game doesnt change that fact much. While it was an interesting addition, it was often tedious leveling up my character just so my grade would be better. I think the class would be better without it."*

A comparison of student perceptions between the gamified and participation point conditions will be captured in the next chapter of this dissertation.

5.7 Discussion

In general, it is clear that gamification did lead to students engage in the non-technical skills of collaboration, communication and time management, though results varied by class format.

The first interesting point to note about the data is that system interactions in the Classcraft tool itself increased from 7.3% in August to 57.3% in September and then peaked in November with 83.6% of students interacting in the tool. These results were surprising given the prior research on the time effect of games and gamification. Other studies have found gamified approaches to be more effective in the short-term [40][43] and, as such, often the recommendation is to avoid semester-long gamified interventions. In my study, however, the data suggests once students understood how to use Classcraft, their interest was sustained until final exams at the beginning of December. Additionally, these system interactions were not only for powers that helped them in class but were also for non-class-related activities such as training pets and buying armor for their character avatar. As an added note, a few students engaged in such activities long after the semester ended.

This along with the survey comments, which clearly aligned with the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54], suggests that students found the Classcraft platform itself to be engaging, perhaps because it satisfied one or more basic psychological and emotional needs.

5.7.1 Time Management

Student comments in the survey were revealing in this area as a number of respondents mentioned time constraints and some specifically cited that they have jobs

and/or families to support. As such, it is perhaps not surprising that the number of students in the face-to-face class who turned in some or all exercises during class time and the number of students in the online class who submitted all of their work in a given week early varied a great deal throughout the semester. This suggests that gamification may not be able to overcome outside factors that prevent students from submitting their work early.

Nonetheless, the early submissions were significantly higher than the non-incentivized class in the F2F1 section where the instructor rewarded early submissions earlier in the semester and more frequently during the first half of the semester. The key takaway here is that gamification is most successful when the desired behavior is rewarded consistently, or as one researcher put it, when gamification is "kept alive" [29].

Additionally, gamification did seem to reduce the number of missing assignments. In the face-to-face sections of the course, where instructors did not assess a health point (HP penalty) for missing work, the percent of students who turned in all of their assigned work was not significantly different from a previous non-incentivized semester with the same instructors. However, in the online section where there was a weekly health point (HP) penalty assessed for missing assignments, a higher percent of students turned in every assignment when compared with the previous, non-incentivized semester suggesting that gamification motivated more students to submit all of their assigned work. This is particularly important in online courses where students lack the in-person encouragement and support of classmates and their instructor.

Likewise, the percent of students in the face-to-face section who missed more than 5 assignments over the course of the semester was not significantly different from the non-incentivized semester whereas in the online section, a lower percent of students turned in every assignment when compared with the previous, non-incentivized semester, again suggesting that Classcraft motivated fewer students to miss more

than 5 assignments.

The transparency in the platform may account for some of these results as students who lost HP went into the delayed damage queue for several days so other students on the team could choose to use their powers to help mitigate damage for their teammate and to earn some XP for themselves. Each week, after I assessed these penalties, I announced to students to check the delayed damage queue. This created a situation where, as one student expressed in the survey, students were motivated to turn in their work so as to "not let their team down". In other words, students may have felt more accountable to one another than they would have otherwise. It is important to note that instructors who wish to use gamification should take care to avoid implementions where grades themselves are visible to other students. In this case, performance in Classcraft was not directly related to course grades, which may account for why none of the students brought up privacy concerns.

Additionally, the way powers were implemented in our course and the procedures for using them promoted time management in a way that I had not anticipated at the beginning of the study. Students had to manage their action points such that they could use certain powers, such as bonus points on tests, by particular deadlines and also had to request the use of such powers via the Google form.

5.7.2 Collaboration

Students made ample use of collaborative powers in Classcraft, motivated perhaps by the XP reward they received as an incentive. However, while I expected the results to reveal that the platform motivated students to collaborate more in the face-to-face sections where they sat with their teammates twice each week than in the online section where they worked independently, the number of collaborative to individual powers used in Classcraft revealed the opposite effect. In the face-to-face sections the ratio of individual to collaborative power usage was 38.18% to 61.82% whereas the ratio of individual to collaborative power usage was 26.74% to 73.26% in the online

class.

In the face-to-face classes, the instructors did not set up a dedicated time for strategizing with their teams within class as it was expected that students would avail themselves of the opportunity. On the other hand, in the online class students were provided with a forum for this purpose and strategizing was incentivized with XP rewards. It is possible that the small amount of XP for using collaborative powers was less motivating than the XP for finishing the in-class exercises before the end of class or that students were simply trying to make good use of class time to work on their assigned, for-credit work.

The dedicated communication venue where students could collaborate in addition to XP incentives for the entire team and the fact that students in the online section had an entire week to complete their for-credit tasks likely had an impact in the online section. This suggests that outcomes may improve in this regard for the face-to-face classes if instructors implemented a team discussion forum and some incentives for using it so students are provided with the time and space to strategize without sacrificing valuable class time.

5.7.3 Communication

In the online class the class forums yielded some promising results in terms of students willingness to communicate with one another. The average number of forum posts per student were far greater in the gamified class than they were in a non-incentivized course in an earlier semester and almost all students participated at least one time. This suggests that the gamified intervention did increase communication among students in the class, which was particularly important in an online context where students often feel isolated. Furthermore, the intervention created an atmosphere that was closer to the flipped sections of the class in that students could work together to resolve any questions or concerns they had about the course content.

There were a number of survey comments that mentioned that students felt moti-

vated to participate in class because of Classcraft, though only one specifically aligned with a relatedness (SDT) [13] or social interaction (U&G) [54] motivational mechanism by citing the course forums. However, it is possible that any intervention that provides incentive for participation would yield similar results. As such, in the next chapter I will compare forum data between the Classcraft gamified semester and the Spring 2018 semester in which I used participation points rather than gamification to incentivize using the forum.

The lack of conclusive results for communication in the face-to-face section can largely be explained by the scalability issues when attempting to implement Classcraft in very large sections. As mentioned, Classcraft does not have teaching assistant accounts or any import capabilities and, as such, the instructors had to manually input all XP awards into the tool. The face-to-face instructors had teaching assistants record student in-class participation, however, this could only be done when teaching assistants were not otherwise busy helping students. This meant that class participation could not be rewarded as consistently as instructors would have preferred.

There were also delays between when students earned the XP award and when it could be logged into Classcraft by the instructors. Rewards for games need to be consistent and as frequent as possible, or as one researcher put it, "gamification needs to be kept alive" [29]. Additionally, in the online class students were accustomed to waiting for responses due to the asynchronous nature of the delivery method whereas the face-to-face nature of the other sections may have created the expectation that rewards for participation would be more immediate than was possible with this particular platform. As such, the scalability issues made for a less-than-ideal situation for incentivizing communication skills in the face-to-face sections.

5.7.4 Student and Instructor Perceptions

Both instructors and students had concerns about the way the game was configured and balanced between character classes. These concerns could be remedied in

future implementations of the tool by adjusting the character powers and by changing policies such as when work is considered to be late.

Additionally, the platform is extremely complex and, as such, both students and instructors noted the steep learning curve that made it difficult for students to understand how the platform worked and how to leverage it to their advantage. This could be remedied with some additional instruction at the beginning of the semester.

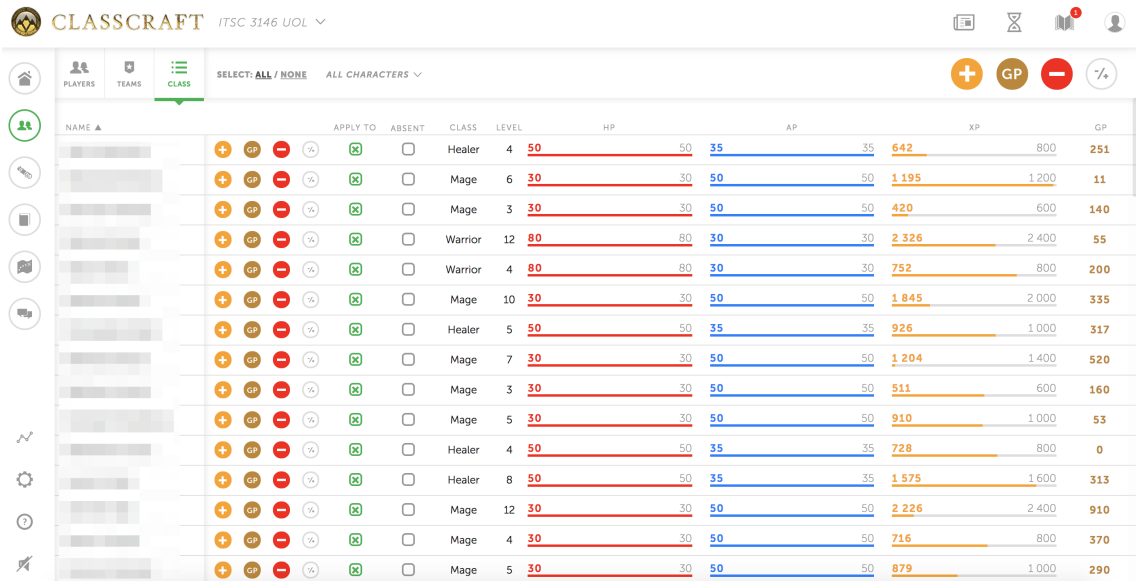


Figure 21: Classcraft Instructor Class Screen

Nonetheless, there were numerous student comments that reflected the motivational mechanisms presented by Self-Determination Theory (SDT) and Uses & Gratification Theory (U&G) and, as such, this suggests that the platform motivated students to engage in non-technical skills and with the tool because the gamified intervention satisfied psychological and emotional needs for some of the students.

5.8 Limitations

Classcraft is a visually stunning tool with plenty of features that students enjoyed such as training pets and customizing their avatar and powers provided an interesting way to encourage students to collaborate with their teams. However, scalability and game balancing were the main limitations encountered in this semester of the study.

Figure 22: Classcraft Team Page

All of the instructors were new to Classcraft and it was highly complex to get the character class powers configured correctly, as indicated by the student surveys. Also, scalability for large classes became quite a challenge. Awarding XP and deducting HP became cumbersome for the instructors as Classcraft does not have teaching assistant accounts and as the tool does not have any import capabilities. With large classes, this became problematic and often led to instructors getting behind and having to catch up. Research has shown that immediate feedback yields better results and the limitations of the tool combined with the size of the sections often delayed feedback.

5.9 Recommendations

Instructors who would like to use Classcraft as a gamification platform in their college classes might want to consider the following recommendations:

Consider class size and delivery method carefully - Larger face-to-face classes (30+ students) absolutely require teaching assistant accounts and import capabilities so it is not recommended to use Classcraft in these situations until these capabilities are included in the tool. A slightly larger online section can work, but only with some automations in place (ie - Google forms for power requests).

Reward desired behaviors consistently and frequently - Gamification as a behavior modification tool works best when students receive clear and consistent feedback as close as possible to performing the desired behavior.

Start small - Start with a small set of important behaviors to reward at first and slowly increase these in subsequent semesters.

Take care when balancing out powers - Powers were very popular with students as they could be leveraged to help their grades. As such, it is important to be sure that all character classes have the same opportunities in the same place on the power tree. For example, students did not like that warriors got their test bonus points at a lower level than healers and mages did.

Flatten the learning curve - Provide some exercises at the beginning of the semester to help teach the students how to use the tool and frequently provide helpful hints and tricks for making the most of powers and Classcraft as the semester goes along.

Provide choice - give the students agency by allowing them to choose whether or not to play. For those who are not keen on gamification, provide an alternative such as the participation points depicted in Chapter 6.

5.10 Conclusions and Future Work

With regard my first research question, "Will gamification provide incentive for students to develop the non-technical skills of collaboration, communication and time management, which are essential to the discipline?" (R3), my results showed that, for the most part, students did miss fewer assignments, did collaborate to help teammates and did communicate with one another when compared with an earlier non-incentivized semester. They also did submit assignments ahead of deadlines when the behavior was rewarded early and often in the first face-to-face section. Furthermore, student survey results indicated that students some of the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54] were present for some students, suggesting that some basic psychological and emotional needs were being met by the gamification intervention.

In future studies, it would be helpful to examine the impact of adding using a tool with capabilities such as teaching assistant accounts and imports in order on the scalability issues.

CHAPTER 6: IMPROVING ENGAGEMENT IN NON-TECHNICAL SKILLS WITH PARTICIPATION POINTS

In the previous chapter I was able to provide some data comparisons with an earlier semester in which there were no incentives for students to engage in non-technical skills and show that the game incentive motivated students. However, in order to isolate gamification versus the incentives themselves, I needed to create a condition with as similar an incentive structure as possible without the game elements. This will allow an assessment of whether it was the game that was engaging or whether students were only responding to incentives for such behaviors and not the game itself. To this end, this chapter depicts the non-gamified condition of the two-semester study where I use participation points instead of game mechanics to incentivize students to engage in non-technical skills.

I will also compare gamified and non-gamified approaches to classroom behavior management as vehicles for providing incentive for students to develop the non-technical skills essential to the discipline of collaboration, communication and time management (R3) (see Section 1.4).

This semester of the study took place over the Spring 2018 semester in two face-to-face sections and one online sections of my university's introduction to operating systems and networking class. In this non-gamified condition, I gathered comparison data on the impact of participation points without any gamification on the same non-technical skills as were measured in the Classcraft condition.

6.1 Setting

The setting is the same as depicted in Chapter 5: Three large sections of the Introduction to Operating Systems and Networking class at UNCC. See Appendix G

for course information. All three sections of the course completed the same course content and activities, available to students via in our Learning Management System, Canvas. The same three instructors taught the course as did in the gamified condition. As in the Fall 2017 semester, the online section, which was taught by me, was asynchronous and the other two sections of the course, which were taught by two other instructors, were offered in a face-to-face format. There were no changes to the course content from the Fall 2017 course so as to isolate the effects of replacing Classcraft as the behavior management tool with the use of participation points.

As in the gamified condition, I used data on forum for the online section and in-class participation for the face-to-face sections as measures of communication. With regard to time management, I looked at early and missing assignment submissions as an indicator that students were managing their time well.

6.1.1 Design

Participation points replaced Classcraft experience points as rewards for early submissions and for participation in class by asking/answering questions or helping other students in F2F1. In F2F2, participation points were awarded for early submissions and there were participation point deductions for missing work. There were no participation points awarded for asking/answering questions or helping other students in this section.

In the online section, Classcraft experience points were replaced by participation points for early submissions and participation on the forums and there were participation point deductions for missing work.

Just as in the Classcraft condition, the face-to-face sections calculated a student engagement score, which was worth 10% of the final course grade, using points and class attendance, though in this case it was participation points rather than Classcraft XP. For the online section, as in the Classcraft condition, engagement was calculated from points alone, again participation points in this case rather than Classcraft XP.

Gamification elements were completely removed, which included perks provided by Classcraft powers and the ability for students to compare their standing compared with the rest of the class. Obviously there were also no avatars, armor customization or pets either.

6.1.2 Procedures

Students were introduced to the engagement score and participation points during the first week of class. See appendix F.

At the end of the semester, I sent a recruitment email for students to complete a brief online survey about their experiences with the engagement score and participation points to the face-to-face classes and I had another professor send a recruitment email to my online class. Students were required to consent to participate in the survey.

Data were collected from the Canvas Learning Management System on assignment punctuality for all three sections and course instructors for the face-to-face sections tracked in-class participation. Forum data were also collected and coded for the online class. Student perceptions of the game and engagement in the course using the Student Course Engagement Questionnaire (SCEQ) proposed by Handelsman et al [27] were also collected. See appendix F for the survey. My study methods and data collection were approved by the University of North Carolina at Charlotte's Institutional Review Board (IRB Number: 17-0320). See appendix I.

6.2 Participants

Study participants were students in the three sections of the Spring 2018 course.

In this semester of the study, 253 computer science majors aged 18-40 ($\mu = 21.97$, $\sigma = 3.47$) participated in the non-gamified condition of the study. The age distribution is depicted in Table 55. Among the participants, 216 (85.4%) were male and 33 (13.0%) were female. The grade point average (GPA) of the participants ranged from

1.25 to 4.0 ($\mu = 3.21$, $\sigma = 0.54$). The race/ethnicity demographics of the participants are shown in Table 56.

Table 55: Spring 2018 Participation Point Age Distribution

Age	**# Participants**	**% Participants**
18 - 24	209	82.61%
25 - 34	36	14.23%
35 - 45	4	1.58%
Not Specified	4	1.58%

Table 56: Spring 2018 Participation Point Race/Ethnicity Demographics

Race/Ethnicity	**# Participants**	**% Participants**
African American	29	11.46%
American Indian	1	0.40%
Any 2 or More Races	14	5.53%
Asian or Pacific Islander 1	36	14.23%
Caucasian	140	55.34%
Hispanic	14	5.53%
International	9	3.56%
Not Specified	10	3.95%

6.3 Results

Due to scalability issues with the Classcraft platform, the data for the two face-to-face classes were not inputted into the tool with the same regularity in the gamified condition as they were tracked in the participation points condition. As such, the data could not be graphed or charted together. Typically, for these sections, I compare the total numbers or percentages, given that a week by week comparison was not possible.

6.3.1 Time Management

Students were rewarded with participation points for turning in work ahead of deadlines. In the case of the face-to-face sections, students were rewarded for submitting their work before the end of the day so as to encourage them to make good use of class time. Note that in the Classcraft semester, this early deadline was at the end of

class rather than the end of the day. Course instructors felt students who struggled with the class material and who needed more time than class allowed should also have the opportunity to earn participation points. As such, this deadline for early submissions was extended for pedagogical reasons. In the case of the online section, there was no change from the Classcraft semester: students were rewarded if they turned in all work for a particular week at least 24 hours before the deadline. Missing work was also penalized with participation point deductions in the online and second face-to-face sections (F2F2).

6.3.1.1 Early Submissions

In the first face-to-face section (F2F1), the instructor began awarding participation points for early submissions on in week 3 of the course. Between 35.34% and 91.38% of students turned in at least one exercise early and received participation points for doing so.

Beginning with week 6 over 70.69% of students in F2F1 consistently turned in at least some of their assigned work early. However, the number of students who turned in all exercises early varied a great deal throughout the semester. See table 57 and figure 23.

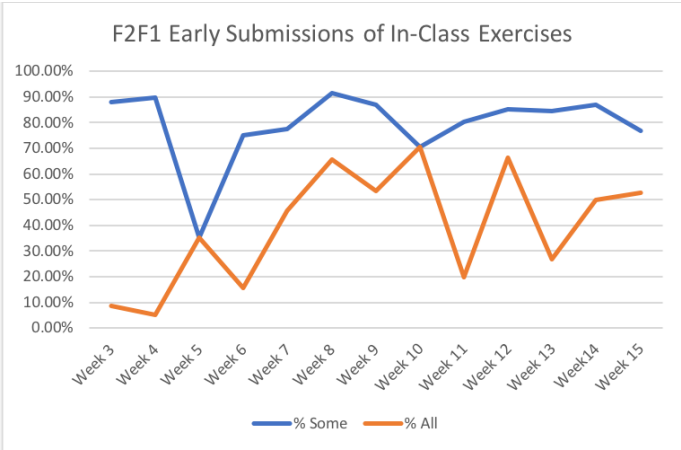


Figure 23: F2F1 Early Submission of In-Class Exercises

When comparing the percent of students who turned in some of their assignments

Table 57: F2F1 Early Completion of In-Class Exercises

Week	**# Some**	**% Some**	**# All**	**% All**
3	102	87.93%	10	8.62%
4	104	89.66%	6	5.17%
5	41	35.34%	41	35.34%
6	87	75.00%	18	15.52%
7	90	77.59%	53	45.69%
8	106	91.38%	76	65.52%
9	101	87.07%	62	53.45%
10	82	70.69%	82	70.69%
11	93	80.17%	23	19.83%
12	99	85.34%	77	66.38%
13	98	84.48%	31	26.72%
14	101	87.07%	58	50.00%
15	89	76.72%	61	52.59%

early in the participation points semester with those who did so in the Classcraft semester (see figure 18 and table 45 in Chapter 5), the mean percent in F2F1 was slightly lower in the participation point semester (79.11%) than in the Classcraft semester (88.97%). This difference, however, was not a statistically significant difference between the Classcraft condition and the participation point condition (p-value = 0.11).

On the other hand, the mean percent of students who turned in all of their work early in the Classcraft semester (61.28%) was higher than in the participation point semester (39.66%) for the F2F1 section. This was a statistically significant difference (p-value = 0.073) and was **despite the change in the deadline for early submissions from the end of class in the gamified semester to the end of the day in the participation point semester**.

In the second face-to-face section (F2F2), the instructor began awarding participation points for early submissions on in week 1 of the course. Between 17.02% and 78.72% of students turned in at least one exercise early and received participation points for doing so.

The percent of students in F2F2 who turned in at least some of their assigned work early tended to fall into the 20 to 40% range throughout the semester, with only two exceptions. See table 58 and figure 24.

Table 58: F2F2 Early Completion of In-Class Exercises

Week	# Some	% Some	# All	% All
1	15	31.91%	13	27.66%
2	13	27.66%	15	31.91%
3	19	40.43%	12	25.53%
4	37	78.72%	8	17.02%
5	15	31.91%	15	31.91%
6	12	25.53%	7	14.89%
7	16	34.04%	15	31.91%
8	10	21.28%	21	44.68%
9	12	25.53%	20	42.55%
10	13	27.66%	13	27.66%
11	18	38.30%	14	29.79%
12	11	23.40%	27	57.45%
13	13	27.66%	23	48.94%
14	14	29.79%	17	36.17%
15	8	17.02%	22	46.81%

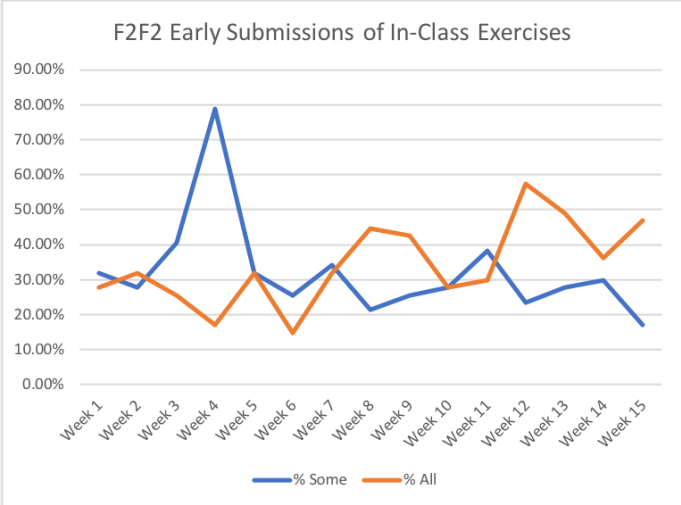


Figure 24: F2F2 Early Submission of In-Class Exercises

When comparing the percent of students who turned in some of their assignments early in the participation points semester with those who did so in the Classcraft

semester (see figure 19 and table 46 in Chapter 5), the mean percent was lower in the participation point semester (32.06%) than in the Classcraft semester (59.64%). While there was not quite a statistically significant difference between the Classcraft condition and the participation point condition (p-value = 0.11), it is interesting to note as it was **despite the change in the deadline for early submissions from the end of class in the gamified semester to the end of the day in the participation point semester**.

The mean percent of students who turned in all of their work early in the Classcraft semester (28.21%) was slightly lower than in the participation point semester (34.33%) for the F2F2 section. This was also not a statistically significant difference (p-value = 0.48).

In the online section between 12.12% and 47.47% of students turned in their assigned exercises at least a day earlier than they were due in a given week. As with the face-to-face sections, the number of students who submitted their work early varied a great deal over the semester. See table 59 and figure 25.

Table 59: Spring 2018 UOL Early Submissions by Week

Week	# Students	% Students
1	33	33.33%
2	19	19.19%
3	27	27.27%
4	15	15.15%
5	12	12.12%
6	26	26.26%
7	22	22.22%
8	34	34.34%
9	33	33.33%
10	47	47.47%
11	30	30.30%
12	32	32.32%
13	30	30.30%
14	30	30.30%
15	32	32.32%

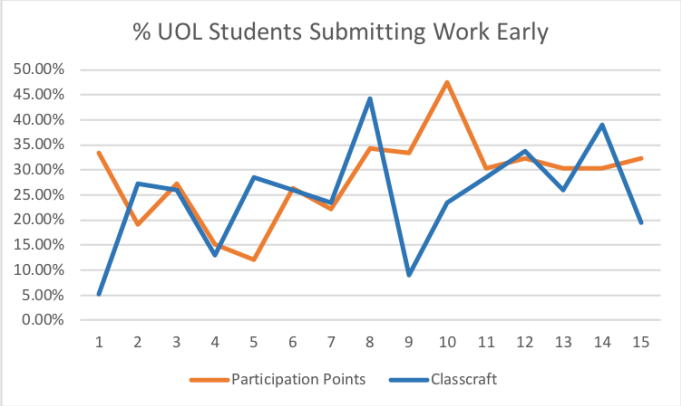


Figure 25: UOL % Students who Submitted all Assigned Work Early

When compared with the Classcraft semester (see figure 25), there was no statistically significant difference for the online section between the Classcraft condition and the participation point condition (p-value = 0.48). The mean percent of students who submitted their all assigned work early was 25.89% in the Classcraft semester and 28.41% in the participation point semester.

6.3.1.2 Missing Submissions

As mentioned earlier, students received a deduction in participation points for failing to turn in assigned work in the online and second face-to-face (F2F2) sections. However, there were no such penalties administered by the instructors of the first face-to-face section (F2F1).

In the F2F1 section, when compared with F2F2 section, a higher percent of students turned in every assignment - 64.35% in the F2F1 section versus 51.06% in the F2F2 section. Also, a lower percent of students failed to turn in more than 5 assignments - 7.83% in the F2F1 section versus 14.89% in the F2F2 section. See table 60.

Furthermore in the F2F1, when comparing the participation point semester to the gamified semester, there was an increase in the percent of students who turned in all assignments from 53.77% in the gamified semester to 64.35% in the participation points semester. There was also a slight decrease in the number of students who

failed to turn in more than 5 assignments from 10.38% in the gamified semester to 7.83%. This difference is unlikely to be related to the gamification versus participation approach, however, as the instructor did not assess penalties for missing work in either semester. See tables 60 and 61.

In the F2F2 section, the instructor did not assess classcraft HP penalties on students for missing work, but did assess participation penalties in the Spring 2018 semester. This addition of participation point penalties to the F2F2 section did not have an impact on the percent of students who turned in all assignments or who had more than 5 missing assignments when compared with the Classcraft gamified semester. Almost the same percent of students turned in every assignment - 51.06% in the F2F1 section of the Spring 2018 participation point semester versus 51.02% in Classcraft semester. Also, almost the same percent of students failed to turn in more than 5 assignments - 14.89% in the participation point semester versus 14.29% in the Classcraft semester. See tables 60 and 61. As these numbers are very similar to those of the non-gamified class as depicted in table 49 in Chapter 5, implementing participation point penalties had little impact on the number of missing assignments in the F2F2 section.

Table 60: F2F Missing Assignments - Participation Points Semester

# Missing Assignments	**F2F1**		**F2F2**	
	# Students	**% Students**	**# Students**	**% Students**
none	74	64.35%	24	51.06%
1	22	19.13%	7	14.89%
2	6	5.22%	3	6.38%
3	1	0.87%	4	8.51%
4	3	2.61%	2	4.26%
5 or more	9	7.83%	7	14.89%

In the online section, on the other hand, where there was a weekly participation point penalty assessed for missing assignments, a lower percent of students turned in every assignment when compared with Classcraft semester - 56.38% in participation

Table 61: F2F Missing Assignments - Gamified Semester

# Missing Assignments	F2F1		F2F2	
	# Students	% Students	# Students	% Students
none	57	53.77%	25	51.02%
1	16	15.09%	8	16.33%
2	9	8.49%	6	12.24%
3	13	12.26%	2	4.08%
4	0	0.00%	1	2.04%
5 or more	11	10.38%	7	14.29%

point semester versus 70.51% in the Classcraft semester. Also, a higher percent of students failed to turn in more than 5 assignments - 15.96% in the participation point semester versus 6.41% in Classcraft semester. See table 62. The participation points semester had very similar results with regard to missing work as in the Spring 2017 non-gamified semester. See table 49 in Chapter 5.

Table 62: UOL Missing Assignments - Participation Points versus Classcraft

# Missing Assignments	Participation Point Semester		Gamified Semester	
	# Students	% Students	# Students	% Students
None	53	56.38%	55	70.51%
1	11	11.70%	12	15.38%
2	5	5.32%	1	1.28%
3	5	5.32%	2	2.56%
4	5	5.32%	3	3.85%
5 or more	15	15.96%	5	6.41%

6.3.2 Collaboration and Communication

It is important to note at the outset of this section that there were collaborative opportunities present in the gamified approach that were just not available in the participation points approach, such as the use of collaborative powers to help a teammate.

6.3.2.1 In-Class Participation

The first face-to-face section (F2F1) rewarded students with participation points for participating in class by asking and answering questions and helping other students. The teaching assistants captured this information and the instructors used it when calculating engagement scores for their classes.

In F2F1, the instructor captured participation for both classes during weeks 2 through 13 and for one class in weeks 14 and 15. In those weeks, between 0.0% and 12.07% of the students were awarded participation points for class participation. See table 63.

Table 63: F2F1 Class Participation with Participation Points

Week	**Points Awarded**	**# Students**	**% Students**
2	8	8	6.90%
3	9	7	6.03%
4	12	10	8.62%
5	6	5	4.31%
6	16	14	12.07%
7	18	13	11.21%
8	8	8	6.90%
9	8	8	6.90%
10	7	6	5.17%
11	7	5	4.31%
12	8	7	6.03%
13	0	0	0.00%
14	0	0	0.00%
15	0	0	0.00%

As the scalability issues made it extremely difficult for instructors to record Classcraft XP in the same time intervals, I compared the total number of times students were rewarded for class participation over each of the semesters. In the Fall 2017 Classcraft semester, the instructor awarded experience points for asking and answering questions or for helping other students during class 86 times over the semester (0.8 times per student). In the Spring 2018 participation point semester, this number was slightly higher. The instructor awarded participation points for asking and answering

questions or for helping other students during class 107 times over the semester (0.99 times per student).

6.3.2.2 Forum Posts

As mentioned in the previous semester, I used forum activity to gauge the level of engagement in the online class, per the findings of the five year study by Barata et al's [1]. As with the Fall 2017 semester, the Spring 2018 online section was provided with weekly Q&A forums where they could ask questions or respond to classmates' questions.

When compared with the baseline semester in Spring 2017 in which there was no incentive provided for forum participation aside from encouraging students to use the forum before reaching out to the instructor or teaching assistants, the addition of participation points in Spring 2018 showed gains in both the number of posts on the forum and in the average number of posts per student. In the participation points semester, 76.53% of the students participated at least one time in the forums compared to 53.6% in the semester without incentives, a gain of 22.96%. Furthermore, the average number of posts per student were 2.4 times greater in the participation points section as in the section without incentives for participation in the forums. See table 64.

However, forum participation decreased with participation points from where it had been using Classcraft. The percent of students who participated in the forums decreased from 97.30% in the gamified semester to 76.53% in the participation points semester, a loss of 20.77%. Additionally, the average number of posts per student were 1.26 times greater in the gamified section as in the section with participation points.

The average number of characters per student was lower in the participation points semester (2300.61) than it was in the gamified Classcraft semester (3051.11) but not significantly so.

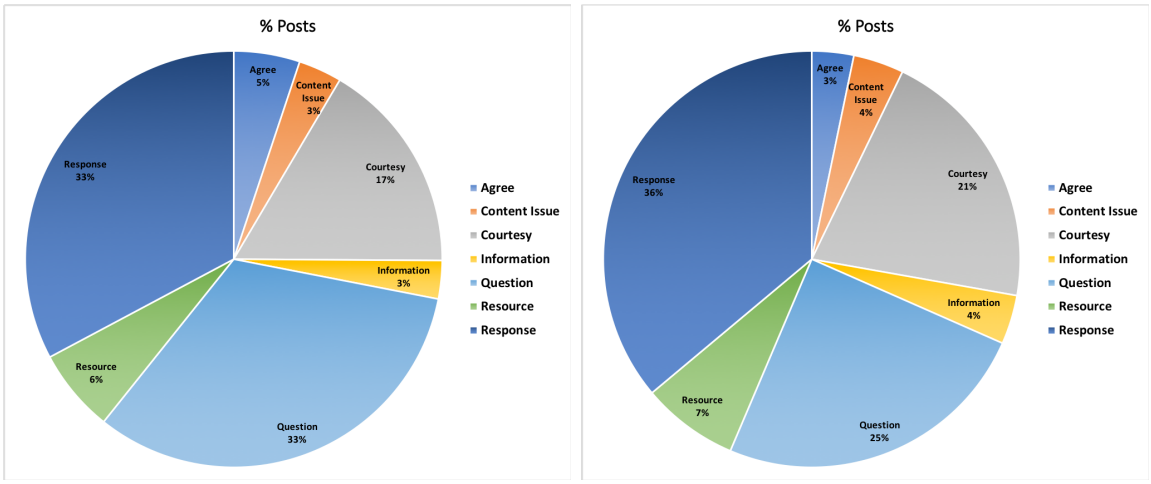
Table 64: Forum Activity by Condition

Condition	# Students in Class	# Posted	% Posted	# Posts	Avg Posts / Student
No Incentives	56	30	53.57%	122	4.1
Gamified	74	72	97.30%	892	12.4
Participation Points	98	75	76.53%	741	9.88

The posts for the participation point and gamified semesters were coded as follows:

- **Agree** - post expressed agreement with another posts
- **Content Issue** - post identified an issue with the course contents
- **Courtesy** - post expressed gratitude for a post or series of posts
- **Information** - post shared helpful information with the class
- **Question** - post asked a question about the course or course content
- **Resource** - post shared a resource with the class
- **Response** - post responded to a classmate's question

In each of the two semesters in the study, the percent of posts falling into each of the above categories were quite similar. See figure 26.



(a) Participation Points - Spring 2018 (b) Classcraft - Fall 2017

Figure 26: UOL % Forum Posts by Code

The codes that captured posts in which students were helping one another with course content were the information, question, resource, and response posts. The percent of posts where students were helping one another navigate the course content were roughly the same in the two semesters of the study. In the participation points

semester, these type of posts constituted 74.90% and in the Classcraft semester, 72.20% of the posts fell into one of these categories. The breakdown of posts with the above codes are depicted in figure 26(a) for the participation points semester and figure 26(b) for the semester gamified with Classcraft.

As such, while both the participation points and gamified conditions incentivized participation in the forum when compared to the baseline semester that included no incentives for forum participation, the percent of students who participated in the forums decreased in the participation point semester from the gamified semester. However, there was no significant difference in the number of characters per student who did participate and a negligible difference between the percent of posts where students helped one another navigate the course content.

6.4 Student Engagement

In both the gamified and participation point semesters of the course, a survey was administered to measure the engagement behaviors and attitudes of students toward the course with Handelsman et al.'s Student Course Engagement Questionnaire (SCEQ) [27]. Some of the wording of the prompts were adjusted to match the course nomenclature (ie - "homework" was changed to "tasks") and to accommodate the online sections of the course (ie - the addition of discussion forum participation to the prompt on asking questions in class). The essential nature of the prompts, however. were unchanged.

Participants were asked to rate each prompt in the questionnaire on the following scale: 1 = *not at all characteristic of me*, 2 = *not really characteristic of me*, 3 = *moderately characteristic of me*, 4 = *characteristic of me*, 5 = *very characteristic of me*.

The SCEQ engagement questionnaire divides the prompts into four types of engagement as follows:

1. Skills - representing student engagement through practical skills

2. Emotional - representing student engagement through emotional involvement with the course materials
3. Participation/Interaction - representing student engagement through participation in class and interactions with instructors and classmates
4. Performance - representing student engagement through performance in class

A similar number of participants responded to the survey in each semester of the study. In the participation point semester, 28 of 36 respondents answered at one or more of the engagement prompts and in the gamified semester 29 of 41 respondents answered one or more of the engagement prompts.

In the original SCEQ questionnaire 9 prompts were included for skills engagement. I included eight of those with the aforementioned edits for nomenclature and to accommodate the online sections of the class as the final prompt (coming to class every day) would not have been applicable to both face-to-face and online sections.

Skills engagement in the participation points semester for each prompt is depicted in table 65. The mean across all skills engagement prompts for the participation semester was 3.57, the median was 4 and the mode was 5.

Skills engagement for the gamified semester for each prompt is depicted in table 66. The mean across all skills engagement prompts for the participation semester was 3.70, the median was 4 and the mode was 4.

There was no significant difference (p-value = 0.28) in the mean of the skills engagement prompts between the participation point and gamified semesters, suggesting that the students who completed the survey did not exhibit more skills engagement in either the participation or gamified semesters of the course.

All five emotional engagement questions in the original SCEQ were included in my survey, with the aforementioned edits for nomenclature and to accommodate the online sections of the class.

Emotional engagement in the participation points semester for each prompt is

Table 65: SCEQ Skills Engagement - Participation Point Semester

Prompt	1	2	3	4	5
Making sure to study on a regular basis	14.29%	14.29%	25.00%	32.14%	14.29%
Putting forth effort	7.14%	7.14%	10.71%	25.00%	50.00%
Completing all of the assigned tasks	7.14%	0.00%	7.14%	14.29%	71.43%
Keeping up with the readings and/or videos	10.71%	7.14%	14.29%	17.86%	50.00%
Reviewing course content between classes to be sure I understand the material	10.71%	14.29%	39.29%	17.86%	17.86%
Being organized	14.29%	21.43%	7.14%	28.57%	28.57%
Taking good notes on the course readings and/or videos	21.43%	28.57%	25.00%	25.00%	0.00%
Listening carefully to the recorded videos and/or during class	10.71%	7.14%	10.71%	21.43%	50.00%

Table 66: SCEQ Skills Engagement - Gamified Semester

Prompt	1	2	3	4	5
Making sure to study on a regular basis	6.90%	20.69%	31.03%	31.03%	6.90%
Putting forth effort	3.45%	3.45%	24.14%	44.83%	24.14%
Completing all of the assigned tasks	0.00%	0.00%	6.90%	17.24%	75.86%
Keeping up with the readings and/or videos	3.45%	10.35%	6.90%	34.48%	44.83%
Reviewing course content between classes to be sure I understand the material	10.35%	20.69%	27.59%	24.14%	17.24%
Being organized	3.45%	13.79%	10.35%	27.59%	44.83%
Taking good notes on the course readings and/or videos	13.79%	24.14%	17.24%	31.03%	10.35%
Listening carefully to the recorded videos and/or during class	6.90%	3.45%	24.14%	37.93%	24.14%

depicted in table 67. The mean across all emotional engagement prompts for the participation semester was 3.16, the median was 3 and the mode was 3.

Table 67: SCEQ Emotional Engagement - Participation Point Semester

Prompt	1	2	3	4	5
Finding ways to make the course content relevant to my life	21.43%	25.00%	14.29%	17.86%	21.43%
Applying course content in my life	17.86%	32.14%	17.86%	14.29%	17.86%
Finding ways to make the course interesting to me	14.29%	10.71%	21.43%	25.00%	28.57%
Thinking about the course between class meetings and/or study sessions	14.29%	7.14%	32.14%	32.14%	14.29%
Really desiring to learn the material	14.29%	7.14%	28.57%	25.00%	25.00%

Emotional engagement in the gamified semester for each prompt is depicted in table 68. The mean across all emotional engagement prompts for the participation semester was 3.06, the median was 3 and the mode was 4.

Table 68: SCEQ Emotional Engagement - Gamified Semester

Prompt	1	2	3	4	5
Finding ways to make the course content relevant to my life	17.24%	24.14%	20.69%	17.24%	20.69%
Applying course content in my life	17.24%	17.24%	24.14%	27.59%	13.79%
Finding ways to make the course interesting to me	6.90%	44.83%	13.79%	17.24%	17.24%
Thinking about the course between class meetings and/or study sessions	13.79%	31.03%	20.69%	27.59%	6.90%
Really desiring to learn the material	6.90%	6.90%	27.59%	44.83%	13.79%

There was no significant difference (p-value = 0.51) in the mean of the emotional engagement prompts between the participation point and gamified semesters, sug-

gesting that the students who completed the survey did not exhibit more emotional engagement in either the participation or gamified semesters of the course.

All six participation/interaction engagement questions in the original SCEQ were included in my survey, with the aforementioned edits for nomenclature and to accommodate the online sections of the class.

Participation/interaction engagement in the participation points semester for each prompt is depicted in table 69. The mean across all emotional engagement prompts for the participation semester was 2.76, the median was 3 and the mode was 1.

Table 69: SCEQ Participation/Interaction Engagement - Participation Point Semester

Prompt	1	2	3	4	5
Raising my hand in class or posting to the course discussion forums	42.86%	14.29%	7.14%	17.86%	17.86%
Asking questions when I don't understand the course content	21.43%	21.43%	17.86%	7.14%	32.14%
Having fun in class or on the discussion forums	28.57%	10.71%	25.00%	32.14%	3.57%
Participating actively in-class group discussions or in the course discussion forums	32.14%	10.71%	10.71%	25.00%	17.86%
Going to the Teaching Assistants' or Professor's office hours to review assignments/tests or to ask questions	53.57%	28.57%	14.29%	3.57%	0.00%
Helping fellow students	17.86%	0.00%	10.71%	35.71%	35.71%

Participation/interaction engagement in the gamified semester for each prompt is depicted in table 70. The mean across all emotional engagement prompts for the participation semester was 2.69, the median was 3 and the mode was 3.

There was no significant difference (p-value = 0.64) in the mean of the participation/interaction engagement prompts between the participation point and gamified semesters, suggesting that the students who completed the survey did not exhibit

Table 70: SCEQ Participation/Interaction Engagement - Gamified Semester

Prompt	1	2	3	4	5
Raising my hand in class or posting to the course discussion forums	24.14%	10.35%	41.38%	13.79%	6.90%
Asking questions when I don't understand the course content	13.79%	17.24%	37.93%	24.14%	6.90%
Having fun in class or on the discussion forums	17.24%	27.59%	20.69%	27.59%	3.45%
Participating actively in-class group discussions or in the course discussion forums	13.79%	20.69%	24.14%	24.14%	13.79%
Going to the Teaching Assistants' or Professor's office hours to review assignments/tests or to ask questions	51.72%	27.59%	17.24%	3.45%	0.00%
Helping fellow students	13.79%	10.35%	34.48%	37.93%	3.45%

more participation/interaction engagement in either the participation or gamified semesters of the course.

All three performance engagement questions in the original SCEQ were included in my survey, with the aforementioned edits for nomenclature and to accommodate the online sections of the class.

Performance engagement in the participation points semester for each prompt is depicted in table 71. The mean across all performance engagement prompts for the participation semester was 4.12, the median was 5 and the mode was 5.

Table 71: SCEQ Performance Engagement - Participation Point Semester

Prompt	1	2	3	4	5
Getting a good grade	7.14%	7.14%	7.14%	28.57%	50.00%
Doing well on the tests and assigned tasks	7.14%	0.00%	14.29%	28.57%	50.00%
Being confident that I can learn and do well in class	7.14%	3.57%	10.71%	25.00%	53.57%

Performance engagement in the gamified semester for each prompt is depicted in

table 72. The mean across all emotional engagement prompts for the participation semester was 3.5, the median was 4 and the mode was 4.

Table 72: SCEQ Performance Engagement - Gamified Semester

Prompt	1	2	3	4	5
Getting a good grade	3.45%	3.45%	20.69%	48.28%	24.14%
Doing well on the tests and assigned tasks	6.90%	6.90%	37.93%	37.93%	10.35%
Being confident that I can learn and do well in class	10.35%	17.24%	20.69%	37.93%	13.79%

There was a significant increase in performance engagement (p-value = 0.00056) in the mean of the performance engagement prompts in the participation point semester compared to the gamified semester, suggesting that the students who completed the survey exhibited more performance engagement in the participation point semester than they did in the gamified semester of the course.

Students were also asked to self-report their engagement overall both in the course and in the course compared to other courses on a six point scale (1= not at all engaged, 6 = extremely engaged/1 = less engaged than in any of my other courses, 6 = more engaged than in any of my other courses).

In both semesters, students self-reported a similar level of engagement in the class. See tables 73 and 74: In the participation points semester the mean was 4.107, the median was 4 and the mode was 4 and in the gamified semester the mean was 4.138, the median was 4 and the mode was 4. In terms of the comparison with other classes, the participation points semester had a slightly higher mean than the gamified semester: In the participation points semester, the mean was 3.929, the median was 4,and the mode was 4, whereas in the gamified semester, the mean was 3.607,the median was 4,and the mode was 4.

6.5 Instructor Perceptions

The two face-to-face instructors had opposite experiences during this study.

Table 73: Self-Reported Engagement - Participation Points

	1	**2**	**3**	**4**	**5**	**6**
How engaged were you in this class?	10.71%	3.57%	10.71%	35.71%	17.86%	21.43%
How engaged were you in this class compared to the other courses you've taken this semester?	10.71%	7.14%	21.43%	25.00%	10.71%	25.00%

Table 74: Self-Reported Engagement - Gamified

	1	**2**	**3**	**4**	**5**	**6**
How engaged were you in this class?	0.00%	13.79%	10.35%	37.93%	24.14%	13.79%
How engaged were you in this class compared to the other courses you've taken this semester?	6.90%	17.24%	20.69%	24.14%	17.24%	10.35%

The first face-to-face instructor felt the participation points semester went more smoothly in general as the participation points system was easier for students to understand than was Classcraft and as the former allowed her to have teaching assistants handle the tracking of points:

> *"From an instructor's point of view, (the participation points) semester was MUCH easier to handle because there was no need to go into Classcraft and enter points for each assignment."*

> *"Once I posted the list of possible ways that students could score engagement points, there were no more than one or two questions about it this semester. Last semester, several students had trouble navigating Classcraft and understanding how it works."*

> *"I found equal participation in class as far as students answering questions and group work went both last semester and this semester. In fact, I would say (the participation points) semester was smoother."*

This instructor did feel that the gamification approach itself was not the issue

but rather felt the tool needed to be better balanced and configured, students needed better instructions at the beginning of the semester and the tool needed either import capability or the ability to add teaching assistant accounts to help track points in large classes. Also, the first face-to-face instructor suggested that students be given the choice of gamification or participation points.

The second face-to-face instructor on the other hand felt the Classcraft semester went better with regard to student interactions:

> *"When compared to my Spring 2018 class, the Fall 2017 class seems to have had a more team-oriented and relaxed atmosphere. I am not sure if this is due to Classcraft; however, I did notice that Classcraft created team-based interactions in and out of the classroom that would not have occurred otherwise."*

Again, as I taught the online section, I will also include my perceptions here with the caveat that these were just observations based on my own personal experiences as the instructor rather than as a researcher.

In comparing the two semesters, I note the following:

> *While I did not notice more collaboration/communication in the gamified semester when compared with the participation point semester, I did notice students seemed to be enjoying themselves more in the former semester.*
>
> *Participation points were easier to track, though not considerably so.*
>
> *There were fewer extreme responses to participation points - students just accepted them as part of the grading scheme. With Classcraft, there were students who absolutely loved it and those who absolutely hated it.*

6.6 Student Perceptions

As with the Classcraft semester, student perceptions of participation points were captured in a survey at the end of the semester after grades had been posted. Again, as I wanted to be sure that students felt they could be honest with their feedback, I had one of the other instructors send the recruiting email to my students and I sent the recruiting email to their classes.

The survey response rate was low in both the participation points (36 respondents) and gamified semesters (41 respondents), perhaps because the survey was sent after grades were posted in each semester to ensure honest student feedback.

Student perceptions of the use of participation points were captured the survey where they were asked the extent to which they agreed with the following statements on a scale of 1 to 4 with 1 representing "strongly disagree" and 4 representing "strongly agree":

1. Participation points were a good addition to the course
2. I wished more of the activities in the course counted toward my participation points
3. Participation points increased my motivation to collaborate with my team or classmates on course materials
4. Participation points increased my motivation to turn in my work ahead of deadlines
5. Participation points increased my motivation to raise my hand in class or to participate in the discussion forums
6. Participation points increased my motivation to help other students

Of the responses, 53.85% of the 26 students who responded to the statement "Participation points were a good addition to the course" either agreed or strongly agreed.

Of the responses, 61.54% of the 26 students who responded to the statement "I wished more of the activities in the course counted toward my participation points" either agreed or strongly agreed.

Of the responses, 30.77% of the 26 students who responded to the statement "Participation points increased my motivation to collaborate with my team or classmates on course materials" either agreed or strongly agreed.

Of the responses, 50.0% of the 26 students who responded to the statement "Participation points increased my motivation to turn in my work ahead of deadlines" either agreed or strongly agreed.

Of the responses, 34.6% of the 26 students who responded to the statement "Participation points increased my motivation to raise my hand in class or to participate in the discussion forums" either agreed or strongly agreed.

Of the responses, 38.46% of the 26 students who responded to the statement "Participation points increased my motivation to help other students" either agreed or strongly agreed. See Figure 27.

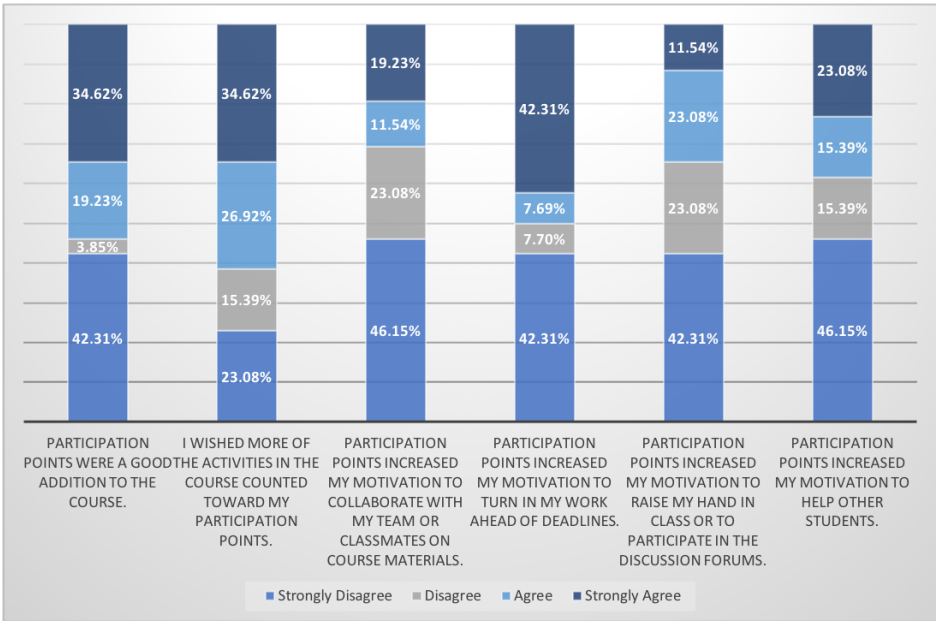


Figure 27: Quantitative Survey Results - Participation Points

Student perceptions of the use of Classcraft were captured the survey where they were asked the extent to which they agreed with the following statements on a scale of 1 to 4 with 1 representing "strongly disagree" and 4 representing "strongly agree":

1. Classcraft was a good addition to the course
2. I wished more of the activities in the course had associated Classcraft rewards
3. Classcraft rewards increased my motivation to collaborate with my team or classmates on course materials
4. Classcraft rewards increased my motivation to turn in my work ahead of deadlines

5. Classcraft rewards increased my motivation to raise my hand in class or to participate in the discussion forums
6. Classcraft rewards increased my motivation to help other students

Of the responses, 28.57% of the 28 students who responded to the statement "Classcraft was a good addition to the course" either agreed or strongly agreed.

Of the responses, 57.14% of the 28 students who responded to the statement "I wished more of the activities in the course had associated Classcraft rewards" either agreed or strongly agreed.

Of the responses, 35.72% of the 28 students who responded to the statement "Classcraft rewards increased my motivation to collaborate with my team or classmates on course materials" either agreed or strongly agreed.

Of the responses, 44.4% of the 28 students who responded to the statement "Classcraft rewards increased my motivation to turn in my work ahead of deadlines" either agreed or strongly agreed.

Of the responses, 25% of the 28 students who responded to the statement "Classcraft rewards increased my motivation to raise my hand in class or to participate in the discussion forums" either agreed or strongly agreed.

Of the responses, 32.14% of the 28 students who responded to the statement "Classcraft rewards increased my motivation to help other students" either agreed or strongly agreed. See Figure 28.

The survey question which asked what students did not like about participation points generated fewer comments (16) than the similar question asking what students liked about Classcraft (22).

The qualitative responses for the Classcraft semester were categorized into motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54] in the Student Perceptions section of Chapter 5. For each category, I explain the words and phrases that I looked for in order to categorize

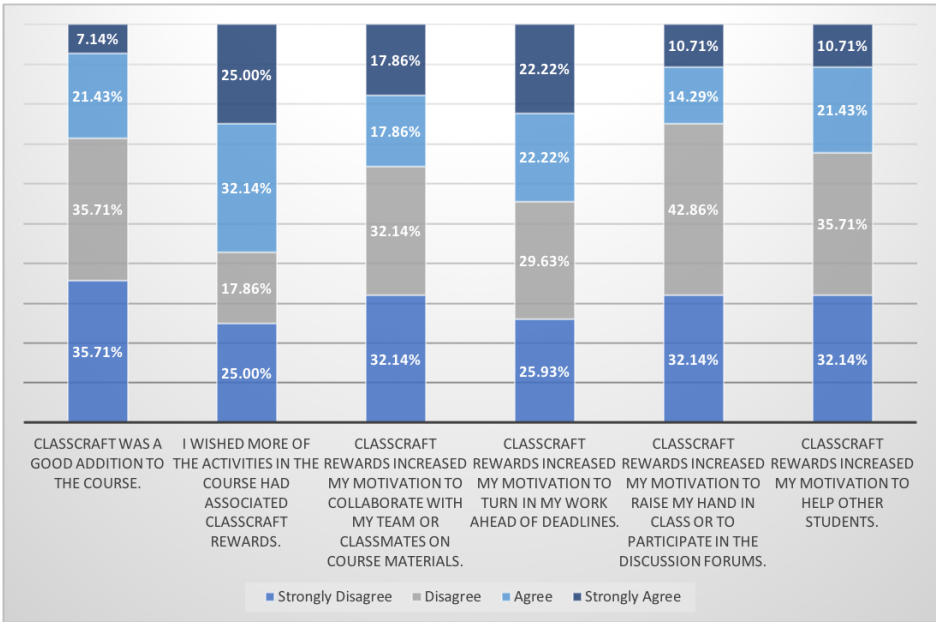


Figure 28: Quantitative Survey Results - Classcraft

the comment into one of the motivational mechanisms. I acknowledge that as this analysis was done by myself, there is the possibility of experimenter bias. However, I endeavored to capture the intent behind each comment as impartially as possible.

There were only two of these motivational mechanisms exhibited in the student comments in the participation points semester: relatedness (SDT)/social interaction (U&G) and competence (SDT)/challenge (U&G).

Of the responses, 23.08% (3/13) of the comments in the participation points semester aligned positively with the relatedness (SDT)/social interaction (U&G) motivational mechanism in that they mentioned words and phrases such as "discuss", "interaction with other students", "speaking in class" and so forth. Two example comments from participants in the study are as follows:

> *"Kept us honest about understanding the material and allowed us to discuss things we didnt understand with each other and have our questions answered."* - P12

> *"I liked that they rewarded interacting with other students, and gave me an outlet to get points for doing something I already would have done."* - P7

However, 15.4% (2/13) of the comments aligned negatively with this motivational mechanism as the system allowed students other outlets for gaining points and so discouraged participating in class. These comments were:

> *"A passive system. They can be achieved just from doing assignments early, it's not only dependent on if you speak up in class. "* - P1

> *"I liked that it was easier to get them than other classes. It's helpful to have the participation points cover more than just "talk in class". It actually helped me to not feel pressured, and allowed me to focus on how I learned more effectively. They were very inclusive of all learning types."* - P2

Of the responses, 23.08% (3/13) of the comments in the participation points survey also aligned with the competence (SDT)/challenge (U&G) motivational mechanism. These comments indicated that participation points provided motivated them to do engage in the targetted behaviors and included words and phrases such as "get my work done early", "incentive", "advance in the game", "go above and beyond", or otherwise indicated that students felt the game left them feeling challenged. One example comment from participants in the study is as follows:

> *"They motivated me to get my work done early."* - P11

In addition to the above motivational mechanisms, one respondent liked that the system was not punitive: *"It was a good addition to this class specifically, there was plenty of time to rack up a full 100 over the semester. Some classes start at 100 and penalize you for not participating once, but this system was a lot better."* - P5

The survey question which asked what students disliked about participation points generated fewer comments (16) than the similar question asking what students disliked about Classcraft (18).

Of the responses, 31.25% (5/16) mentioned that they felt the system punished them for not interacting in class or on the forums. Two example comments from participants in the study are as follows:

> *"I dont think you should be necessarily punished if you dont have anything to say."* - P17
>
> *"It felt like i was being punished for understanding the material without asking questions and being too busy to effectively help other students."* - P7

Of the responses, 25% (4/16) felt early submissions should not have been included in the participation points. An example of one of these comments is: *"Personally, I think a class like this shouldn't have our grade reflect how early we did assignments. It would be nicer if they were more of a bonus to our grade than a negative."* - P10

Of the responses, 6.25% (1/16) cited the difficulty tracking participation points: (*"Having to keep track of what I had done that quarter was (only slightly) frustrating, but I'm sure if I had participate more than enough, I wouldn't have felt that way."* - P5) and 6.25% (1/16) of the respondents mentioned Piazza rather than Canvas forums would have been a better choice for the online class.

6.7 Discussion

In general, although Classcraft was a little more effective at motivating students to engage in certain non-technical skills in general, participation points do provide some incentive and are less likely to elicit extreme negative responses for some students. However, Classcraft provided several unique incentives to students that could not be replicated with participation points. The stunning visuals with an avatar that can be customized with seasonally-themed armor and pets that can be collected and trained were genuinely engaging for many of the students. Additionally, the collaborative powers that encouraged students to help one another just could not be replicated, which was unfortunate as they led to the perceptions of a more collaborative environment for some students and for two of the three instructors.

6.7.1 Time Management

As in the gamified condition, the number of students in all three sections who turned in all exercises early varied a great deal throughout the semester, suggesting

that participation points may not be able to overcome outside factors, such as time constraints, that prevent students from submitting their work early.

However, when examining missed assignments between the two conditions for the F2F1 section, where the instructor rewarded students earlier and more frequently than in the other face-to-face section, the data revealed a statistically significant increase in the percent of students who turned in all of their assigned work early in the Classcraft semester when compared to the participation points semester. In the second face-to-face section (F2F2) section, there was also an increase in the percent of students who finished some or all of their assigned work early in the Classcraft semester when compared to the participation point semester, though neither of these increases were statistically significant. However, the statistically significant increase in F2F1 along with the increases in F2F2 **despite the fact that deadlines had been extended to the end of the day in the participation points semester** would suggest that Classcraft was more effective at incentivizing early submissions in the face-to-face sections.

This was not the case in the online section, where students had to turn in all work for a given week at least a day ahead of deadlines. Participation points and gamification both provided about the same amount of incentive for turning in work early.

As for missing submissions, in the end, I could not draw any conclusions about the impact of gamification in the face-to-face sections as neither instructor assessed HP penalties for missing assignments. In the participation points semester, however, F2F2 implemented a penalty for missing submissions and, as such, I expected fewer students with missing assignments in the second face-to-face (F2F2) section than in the first (F2F1). However, this was not the case. The addition of participation point penalties did not seem to impact the number of missing submissions in the second face-to-face section and would suggest that there were other factors that led

to students missing assignments, such as time constraints, assignment difficulty and so forth.

In the online section, however, gamification had more of an impact than participation points both in terms of increasing the percent of students who turned in every assignment and decreasing the percent of students who failed to turn in more than 5 assignments over the course of the semester. Transparency provided in the Classcraft platform may account for some of these results as students were aware of which teammates lost HP for missing assignments in the gamified condition whereas students had no visibility into who had earned or lost participation points in the participation point condition. This may have reduced student accountability with one another resulting in more missing assignments in this non-gamified semester than in the gamified semester.

The participation points condition was also missing the added time management practice in that students had to manage their action points such that they could use certain powers, such as bonus points on tests, by particular deadlines. Participation points were rewarded automatically and one student even commented that they liked the "passive" nature of the incentive scheme.

6.7.2 Collaboration and Communication

One of the major drawbacks to using participation points instead of Classcraft was that there was no way to implement something that mirrored collaborative powers without also including a way for students to see how other students were doing, which would be a leaderboard-like game element. Additionally, powers were tied directly to game incentives and character classes.

In Classcraft, results showed that students frequently used collaborative powers to help their teammates. This, in and of itself, helped achieve the goal of motivating students to engage in collaborative skills. Furthermore, in the online class, team forums revealed students strategizing and collaborating with one another and the F2F2

instructor noticed that Classcraft created team interactions and collaborations that did not occur in the participation point semester. The participation point condition did not have any incentive mechanism in place to promote team collaboration other than a few points awarded by the F2F1 instructor for helping other students.

Only the first face-to-face section (F2F1) awarded Classcraft XP or participation points for asking and answering questions and helping other students. These awards could not be compared to the gamified condition by week or even quarter as there was a delay between the time they were awarded by teaching assistants and when they were inputted into Classcraft. As such, I compared the total number of participation events recorded per student for each semester and found only a slight increase in the number of participation events recorded per student in the participation points semester (0.99) versus the Classcraft semester (0.8). As such, the two approaches have very similar effects on incentivizing students to participate in class though it is possible that gamification could be more effective if there were a way reward students more immediately and consistently in Classcraft. However, this is not currently possible in this particular tool.

In the online class, on the other hand, while both gamification and participation points led to increases in the percent of students who participated at least once in the forums over the course of the semester when compared to an earlier semester without incentives, the percent of students who participated at least once was significantly higher in the gamified semester than in the participation points semester. Furthermore, the percent of posts where students were interacting about the course content were very similar between the two semester, suggesting that gamification was more effective at incentivizing participation in the forums without sacrificing the percent of posts where students were engaged with one another about the course and course content. It may simply be that Classcraft was more effective because the gamified condition satisfied more basic psychological and emotional needs through the mo-

tivational mechanisms presented by Self-Determination Theory (SDT) and Uses & Gratification Theory (U&G) than did the participation points approach.

6.7.3 Instructor and Student Perceptions

As mentioned, each of the two face-to-face instructors had opposite reactions to the effectiveness of the two approaches: gamification or participation points. The first instructor felt students were more confused and found scalability with Classcraft to be a challenge in her class of over 100 students. The second instructor, who had a much smaller class, felt Classcraft created a better team atmosphere in his class when compared with the participation point semester. However, addressing some of the balancing and scalability issues with Classcraft or implementing a different gamification platform may have led to a more positive experience for the instructor of the larger class.

Insofar as student perceptions were concerned, more of the comments from the gamified semester reflected the motivational mechanisms presented by Self-Determination Theory (SDT) and Uses & Gratification Theory (U&G) than in the participation points semester. This may help understand why a higher percent of students collaborated on the discussion forums in the gamified online class and why a higher percent of students in the gamified face-to-face sections turned in work early or missed fewer assignments. However, again due to the small number of respondents, more research is needed in this area.

It is also important to note that while the majority of the negative comments expressed that students did not like game balancing or how it was implemented, a relatively few students expressed that they did not like Classcraft and/or found it to be inappropriate for a college setting. However, student perceptions fell into the extremes in the gamified condition more-so than they did in the participation point condition. Allowing students to choose between gamification and a more traditional scheme such as participation points would be helpful at mitigating some of the nega-

tive perceptions. Additionally, balancing the powers more carefully as recommended in Chapter 5 would help mitigate many of the negative comments associated with Classcraft.

6.7.4 Engagement

In order to measure the impact of the interventions on the two different incentive approaches on engagement, I included Handelsman et al.'s Student Course Engagement Questionnaire (SCEQ) [27]. However, it is important to note that there were very low response rates for the survey in both semesters, possibly due to the recruitment email going out after grades were posted so students would not be concerned that their responses might impact their grades.

The results of this comparison did not show a significant differences between the gamified and participation point semesters in skills, emotional and participation/interaction engagement. Performance engagement, which measures engagement through performance in class, however, was higher in the participation point semester than in the gamified semester. Self-reported engagement was about the same for both semesters when reporting engagement in the class and a little lower in the gamified semester when comparing the class to other classes in the same semester.

It is possible that some of the students found the class to be less engaging in some regards as a result of gamification than they would have with participation points. However, due to the low response rate of the surveys, I am reluctant to draw any conclusions from this data. More research needs to be done to gather more results to determine the effect of gamification versus participation points on engagement.

Nonetheless, providing choice to students at the beginning of the semester may well resolve any issues underlying issues around engagement as students who are not keen on playing games or feel that it is childish in a college context can opt out.

6.8 Limitations

Both Classcraft and participation points seem to provide viable options to motivate students to engage in non-technical skills practice. However, the low response rate of both surveys in the study limited the data I could compare on engagement and student perceptions. Also, due to scalability issues, it was extremely diffcult to compare the gamified semester with the participation points semester for the face-to-face sections as instructors were not able to award XP on a weekly basis in the gamified semester but with teaching assistant help, could do so in the participation point semester.

6.9 Conclusions and Future Work

With regard to my first research question, 'Will gamification provide incentive for students to develop the non-technical skills of collaboration, communication and time management, which are essential to the discipline?" (R3), my results show that my results clearly show that it can.

Time management was positively impacted by gamification in both the online and face-to-face sections, though in different ways. In the online section, gamification had a clear advantage in reducing missed assignments over participation points. In the face-to-face classes, despite the fact that deadlines had been extended to the end of the day in the participation points semester, a higher percent of students turned in work early in the one of the face-to-face sections in the gamified semester, suggesting that gamification could be more effective at incentivizing early submissions, though more research would be needed to draw any definitive conclusions to this effect. Finally, Classcraft afforded students additional opportunities to practice time management skills as they had to manage their action point accumulations to meet deadlines for certain power requests.

In terms of communication, a higher percent of students in the online class participated on the forum in the gamified semester than either the participation point

non-incentive semester and students, suggesting that gamification does improve communication in online classes.

Finally, with regard to collaboration, while the online section used more collaborative powers in Classcraft, the face-to-face class also made ample use of them. These collaborative powers were a unique way to promote team-work in class, and one of the face-to-face instructors felt that this contributed to a more team-oriented atmosphere.

While students self-reported similar course engagement scores for both the gamified and participation point semesters, student survey comments revealed more of the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54] in the gamified semester than in the participation points semester suggesting that students may have been more motivated.

These results are promising, but need further investigation to more deeply understand how and when such gamification approaches can engage students and how to best implement it in large college classes. Also, as some students felt that Classcraft was not appropriate for college and as participation points did incentivize these behaviors, a follow-up study could investigate allowing students a choice between gamified and participation points approaches for assessing engagement.

CHAPTER 7: CONCLUSIONS AND FUTURE WORK

As mentioned earlier in this dissertation, very little of game and gamification research explores whether these approaches would motivate students to go beyond course requirements. However, for computer science students, there are a great many technical and non-technical skills critical to success in the discipline that simply cannot be squeezed into coursework. The one study that did examine the impact of gamification on students' willingness to go beyond course credit was done by Ibanez et al. [30]. While these researchers found that 20/22 students continued to work on the C programming questions after they had achieved 100% in the course, this sample was extremely small.

In general, however, computer science co-curricular activities are limited to heavy-weight events such as hack-a-thons and capture-the-flag competitions, which typically require a great deal of skill mastery, time on the part of students and faculty, and funding for travel. As such, most students do not participate and, therefore, do not reap the benefits.

Finally, there is little research that explicitly addresses the impact of games and gamification on non-technical skills with the exception of Topîrceanu [57], who demonstrated that gamified undergraduate Algorithm Design and Analysis and Computer Organization classes had higher attendance, homework and quiz completion than non-gamified classes. However, Topîrceanu's study was only addressed these aspects of time management in small face-to-face classes of between 17 and 52 students and did not address collaboration or communication at all.

7.1 Contributions

In my studies it was demonstrated that games and gamification, by satisfying the important psychological and human needs expressed by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory (U&G) [54], did, indeed, motivate students to engage in skills practice beyond what is required for course credit as follows:

R1. Will games provide incentive for students to go beyond the requirements for course credit to develop technical skills?

In both of the studies characterized in Chapters 3 and 4, my results, when compared to those presented by Ibanez et al. [30], show that while it is possible to achieve a very high percent of students who will engage beyond what is required, the actual percent tends to vary from semester to semester. Nonetheless, my results clearly show that students went on to complete more game levels than were required for course credit, creating an opportunity for those students to spend more time practicing their BASH or Ruby programming skills.

It is also important to note that there was no demographic correlation between completion times or levels and race/ethnicity, age or gender but there there was a correlation found between completion levels in the first study and student GPA. More research should be done on this correlation between GPA and student willingness to go beyond what is required for course credit.

Results also indicate that when there were no for-credit levels in subsequent weeks in the Increasing Programming Practice with a Serious Game study depicted in Chapter 4, a much smaller percent of students continued to play the game than in the first week seeming to confirm the research that suggests that gamified approaches are more effective in the short-term [40][43]. Nonetheless, some students were motivated enough by the game itself to return to it without any grade incentive to do so.

Future work could examine whether or not the addition of a 'hook' in the form of a small percent of course credit for additional levels in subsequent weeks would

increase the percent of students who complete additional levels beyond those that are required. Additionally, an examination of how adjusting the number of required levels would impact the percent of students who complete additional levels could be useful.

The comments on the surveys in both studies provided insight into as to why so many students were motivated to engage in extra technical and programming skills practice even without course credit. In both of these studies, not only did students express that they found the games to be enjoyable, but their comments aligned well with the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54]. In essence, students were motivated to continue to play because the games satisfied some subset of the following needs: autonomy (SDT)/control (U&G), competence (SDT)/challenge (U&G), competition (U&G), fantasy (U&G), interest (U&G), diversion (U&G) and/or relatedness (SDT)/social interaction (U&G).

The most prevalent of the motivational mechanisms expressed in students comments across both of these studies were competence (SDT)/challenge (U&G) and interest (U&G). Challenge, in particular, is important since while I did not examine learning outcomes, challenge was found have a strong correlation with learning outcomes in Hamari et al.'s [26] study. Additional research in this area could be fruitful.

It is also important to note that unlike Schreuders' and Butterfield's [53] study of a gamified cybersecurity module where the outcomes were insufficient to justify the additional load on the instructors, neither of these interventions increased grading or instructional load and, in fact, the BASH game was completely auto-graded. As such, the benefits were achieved with minimal instructional intervention.

Which game elements (leaderboards, badges etc.) provide incentive for students to go beyond the requirements for course credit to develop tech-

nical skills?

While I was only able to gather survey data on this research question in the studies depicted in Chapters 3 and 4, the results do indicate that badges and leaderboards did boost motivation for some students to go beyond the required levels and even to learn the topic.

As in the study by Ibanez et al. [30], where surveys indicated that many students continued working on C programming tasks beyond earning the maximum possible score so as to earn all of the badges, survey data did reveal that a high percent of students who completed the survey were motivated by the possibility of earning badges. However, the response rate was low in the study survey and I was only able to gather data in one semester in the Chapter 3 study.

Regarding the leaderboard in the Chapter 4 study, quantitative survey results indicated that the leaderboard was a motivating element for at least some students. Additionally, there were students who specifically mentioned the leaderboard in the responses to the qualitative question about what they liked about Ruby Warrior or what motivated them to continue past the required levels, though the majority of survey comments had to do with how the game as a whole satisfied psychological or emotional needs.

Future research could be done to isolate the impact of leaderboards or badges, perhaps with a between-subjects study design as I was only able to capture results through survey data. Additionally, it would be useful to add a survey question to try to identify students who were competition-averse and, as such, disincentivized by badges and leaderboards.

Nonetheless, the results do show that badges and leaderboards have a positive impact on motivation for some students and therefore they are a useful addition in that they help increase the number of students who do more than what is required for course credit.

Will gamification provide incentive for students to develop the non-technical skills of collaboration, communication and time management, which are essential to the discipline?

In the studies described in Chapters 5 and 6, while scalability issues made it extremely difficult to compare the gamified semester with the participation points semester for the face-to-face sections, results do indicate that the gamified approach was more effective than a non-gamified participation points approach in the following ways:

- Collaboration: Students in both the online and face-to-face sections made ample use of collaborative powers to help teammates through out the semester in the gamified semester, though the percent of collaborative powers used in the online section was far higher in the online section due to the supportive infrastructure set up to encourage strategizing as a team.

- Communication: In the online class, students communicated with one another more on the course forums than in a previous non-incentivized semester and than in the participation point semester.

- Time-Management: Students in the online section missed fewer assignments than in a previous non-incentivized semester and than in the participation point semester. Also, a significantly larger number of students turned in work ahead of deadlines in the face-to-face section that rewarded early submissions earlier and more frequently. Finally, Classcraft afforded students additional opportunities to practice time management skills as they had to manage their action point accumulations to meet deadlines for certain power requests.

The aforementioned time management results do align with Topîrceanu's [57] findings about the gamified undergraduate Algorithm Design and Analysis and Computer Organization classes having higher homework and quiz completion, at least for the

online section. Additionally, the results extend these findings with gains to collaboration and communication for students in the gamified semester. More research should be done to explore how to implement gamification in large face-to-face classes in a scalable way so the results will be closer to those observed in the online section of the class.

Again, the comments on the surveys provided insight into as to why the gamified approach was more effective than the non-gamified approach. Student comments revealed the gamified approach satisfied more of the motivational mechanisms presented by Self-Determination Theory (SDT) [13] and Uses & Gratification Theory [54]. In essence, students were motivated more by the gamified approach because it satisfied more of the following needs: autonomy (SDT)/control (U&G), competence (SDT)/challenge (U&G), competition (U&G), fantasy (U&G), interest (U&G), diversion (U&G) and/or relatedness (SDT)/social interaction (U&G).

As with the other two studies, the most prevalent of the motivational mechanisms expressed in students comments across in this study was competence (SDT)/challenge (U&G) and interest (U&G). However, it is important to note that the low response rate of the surveys in both semesters of the study limited the data I could compare on engagement and student perceptions.

Also, as some students expressed that they either dislike games or felt that Classcraft was not appropriate for college and as participation points did incentivize these behaviors, a follow-up study could investigate allowing students a choice between gamified and participation points approaches for assessing engagement. This would have to be carefully designed and implemented, however, so students understood that there are some things that just cannot be replicated in the participation points scheme.

7.2 Recommendations

Instructors who would like to use games or gamification in their college classes might want to consider the following recommendations:

Consider class size and delivery method carefully - Larger face-to-face classes (30+ students) absolutely require that game or gamified interventions do not add to instructional load. This can be done with auto-grading and/or by choosing gamification platforms that include such things as teaching assistant accounts and import capabilities.

Reward consistently and frequently in gamification interventions - Gamification as a behavior modification tool works best when students receive clear and consistent feedback as close as possible to performing the desired behavior or demonstrating the desired learning outcome.

Start small - Start with a small set of learning outcomes or behaviors to incentivize at first and slowly increase these in subsequent semesters.

Include a hook - Game or gamified interventions should be set up with some tie in to course credit as a hook to get them started.

Flatten the learning curve - Provide scaffolding to help students understand how the game or gamified intervention works.

Provide choice - if possible, give the students agency by allowing them to choose whether or not to play or even how the game will be implemented, particularly in long term interventions.

Include game elements as boosts to participation - Game elements such as badges and leaderboards can be used to boost participation without adding significantly to instructional load.

7.3 Conclusions and Future Work

In conclusion, games, game elements and gamification can, indeed motivate computer science students to engage in additional technical skills and non-technical collaborative, communication and time-management skills practice beyond what is required for course credit.

Going forward, it would be interesting to examine whether the addition of a 'hook' in the form of a small percent of course credit in subsequent weeks of a game would increase participation in those weeks. It could also be fruitful to explore how changing the mandatory and optional levels would impact how many students continued on to complete optional levels.

Also, as mentioned earlier, a between-subjects study design may help isolate the precise impact of game elements such as badges or leaderboards, but more interestingly, future research could include analysis on how the demographic data relate to SDT/U&G motivational mechanisms. Are certain genders or races/ethnicities more likely to be motivated by competition or challenge or any of the other motivational mechanisms?

Finally, further investigation should be done to more deeply understand how and when such games and gamification approaches can engage students and how to best implement them in large college classes.

REFERENCES

[1] G. Barata, S. Gama, J. Jorge, and D. Gonçalves. Improving participation and learning with gamification. In *Proceedings of the First International Conference on gameful design, research, and applications*, pages 10–17. ACM, 2013.

[2] R. Bates. Ruby Warrior. https://github.com/ryanb/ruby-warrior, 2012. Accessed: 2017-09-03.

[3] Blizzard. World of warcraft. https://worldofwarcraft.com/en-us/, 2018. Accessed: 2018-5-11.

[4] P. Buckley and E. Doyle. Gamification and student motivation. *Interactive Learning Environments*, 24(6):1162–1175, 2016.

[5] U. B. Ceipidor, C. M. Medaglia, A. Perrone, M. De Marsico, and G. Di Romano. A museum mobile game for children using qr-codes. In *Proceedings of the 8th International Conference on Interaction Design and Children*, pages 282–283. ACM, 2009.

[6] Classcraft. https://www.classcraft.com. Accessed: 2017-09-03.

[7] Classcraft. Present classcraft to your students. https://youtu.be/zgcxo3dVcTU, 2018. Accessed: 2018-5-11.

[8] Cloud9. Integrated development environment in the cloud. https://c9.io, 2017. Accessed: 2017-07-24.

[9] Codecademy. https://www.codecademy.com. Accessed: 2017-09-03.

[10] M. Csikszentmihalyi. Flow. the psychology of optimal experience. new york (harperperennial) 1990. 1990.

[11] A. Dabrowski, M. Kammerstetter, E. Thamm, E. Weippl, and W. Kastner. Leveraging competitive gamification for sustainable fun and profit in security education. In *2015 USENIX Summit on Gaming, Games, and Gamification in Security Education (3GSE 15)*. USENIX Association, Aug. 2015.

[12] E. L. Deci, R. Koestner, and R. M. Ryan. A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, 125:627, 1999.

[13] E. L. Deci and R. M. Ryan. Intrinsic motivation inventory. *Self-Determination Theory*, 267, 2003.

[14] S. Deterding. Situated motivational affordances of game elements: A conceptual model. In *Gamification: Using game design elements in non-gaming contexts, a workshop at CHI*, 2011.

[15] S. Deterding, D. Dixon, R. Khaled, and L. Nacke. From game design elements to gamefulness: Defining "gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11, pages 9–15. ACM, 2011.

[16] DragonBox. DragonBox Elements. http://dragonbox.com/products/elements/, 2017. Accessed: 2017-07-17.

[17] W. Erstad. Computer programmer skills: The perfect balance of hard & soft skills employers are seeking. http://www.rasmussen.edu/degrees/technology/blog/5-soft-skills-programmers-need/, 2017. Accessed: 2017-09-12.

[18] T. R. Flushman, M. Gondree, and Z. N. J. Peterson. This is not a game: Early observations on using alternate reality games for teaching security concepts to first-year undergraduates. In *Proceedings of the 8th USENIX Conference on Cyber Security Experimentation and Test*, CSET'15, pages 1–1. USENIX Association, 2015.

[19] S. F. Forde, E. D. Mekler, and K. Opwis. Informational vs. controlling gamification: A study design. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, CHI PLAY '15, pages 517–522, New York, NY, USA, 2015. ACM.

[20] Gamasutra. Pulse!! First Person Healthcare System Simulation. http://www.gamasutra.com/view/news/102373/SGS/Feature/Pulse/First/Person/Healthcare/System/Simulation.php/, 2006. Accessed: 2017-07-17.

[21] GameLearn. Pacific. https://game-learn.com/game-based-learning-corporate-training/serious-game-in-leadership-and-team-management/. Accessed: 2017-07-17.

[22] E. Games. CoLoBoT. http://www.ceebot.com/colobot/index-e.php, 2017. Accessed: 2017-10-03.

[23] N. A. Giacobe and R. Kohler. Development of polymorphic homework and laboratory assignments in cyber security with polylab. In *NICE (National Initiative for Cyber Education) Conference*, 2016.

[24] C. Girard, J. Ecalle, and A. Magnan. Serious games as new educational tools: how effective are they? a meta-analysis of recent studies. *Journal of Computer Assisted Learning*, 29(3):207–219, 2013.

[25] J. Hamari, J. Koivisto, and H. Sarsa. Does gamification work? – a literature review of empirical studies on gamification. In *2014 47th Hawaii International Conference on System Sciences*, pages 3025–3034, Jan 2014.

[26] J. Hamari, D. J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, and T. Edwards. Challenging games help students learn: An empirical study on engagement, flow

and immersion in game-based learning. *Computers in Human Behavior*, 54:170–179, 2016.

[27] M. M. Handelsman, W. L. Briggs, N. Sullivan, and A. Towler. A measure of college student course engagement. *The Journal of Educational Research*, 98(3):184–192, 2005.

[28] M. D. Hanus and J. Fox. Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education*, 80:152 – 161, 2015.

[29] A. C. Y. Hung. A critique and defense of gamification. *Journal of Interactive Online Learning*, 15(1), 2017.

[30] M. B. Ibanez, A. Di-Serio, and C. Delgado-Kloos. Gamification for engaging computer science students in learning activities: A case study. *IEEE Transactions on Learning Technologies*, 7(3):291–301, July 2014.

[31] A. Iosup and D. Epema. An experience report on using gamification in technical higher education. In *Proceedings of the 45th ACM technical symposium on Computer science education*, pages 27–32. ACM, 2014.

[32] Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM) and IEEE Computer Society. *Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science*. ACM, 2013. 999133.

[33] K. M. Kapp. *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons, 2012.

[34] E. Katz. Utilization of mass communication by the individual. *The Uses of Mass Communications Current Perspectives on Gratifications Research*, pages 19–32, 1974.

[35] F. Khaddage and C. Lattemann. Towards mobilizing mathematics via gamification and mobile applications. *Mobile Learning and STEM: Case Studies in Practice*, page 263, 2015.

[36] R. N. Landers and A. K. Landers. An empirical test of the theory of gamified learning. *Simulation & Gaming*, 45(6):769–785, 2014.

[37] L. Laporte and B. Zaman. Informing content-driven design of computer programming games: a problems analysis and a game review. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, page 61. ACM, 2016.

[38] C. Latulipe, N. B. Long, and C. E. Seminario. Structuring flipped classes with lightweight teams and gamification. In *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, pages 392–397. ACM, 2015.

[39] M. J. Lee, F. Bahmani, I. Kwan, J. LaFerte, P. Charters, A. Horvath, F. Luor, J. Cao, C. Law, M. Beswetherick, et al. Principles of a debugging-first puzzle game for computing education. In *Visual Languages and Human-Centric Computing (VL/HCC), 2014 IEEE Symposium on*, pages 57–64. IEEE, 2014.

[40] J. Looyestyn, J. Kernot, K. Boshoff, J. Ryan, S. Edney, and C. Maher. Does gamification increase engagement with online programs? a systematic review. *PLOS ONE*, 12(3):1–19, 03 2017.

[41] J. McGonigal. *Reality is Broken: Why Games Make Us Better and How They Can Change the World*. Jonathan Cape, Feb. 2011.

[42] E. D. Mekler, F. Brühlmann, A. N. Tuch, and K. Opwis. Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior*, 2015.

[43] E. D. Mekler, F. Brhlmann, K. Opwis, and A. N. Tuch. Do points, levels and leaderboards harm intrinsic motivation?: an empirical analysis of common gamification elements. In L. E. Nacke, K. A. Harrigan, and N. Randall, editors, *Gamification*, pages 66–73. ACM, 2013.

[44] J. Mirkovic and P. A. H. Peterson. Class capture-the-flag exercises. In *2014 USENIX Summit on Gaming, Games, and Gamification in Security Education (3GSE 14)*. USENIX Association, Aug. 2014.

[45] M. Muratet, P. Torguet, J.-P. Jessel, and F. Viallet. Towards a serious game to help students learn computer programming. *International Journal of Computer Games Technology*, 2009:3, 2009.

[46] M. Muratet, P. Torguet, F. Viallet, and J.-P. Jessel. Experimental feedback on prog&play: a serious game for programming practice. In *Computer Graphics Forum*, volume 30, pages 61–73. Wiley Online Library, 2011.

[47] OverTheWire. Bandit. http://overthewire.org/wargames/bandit/, 2017. Accessed: 2017-07-24.

[48] Perna, Laura W. Understanding the working college student. https://www.aaup.org/article/understanding-working-college-student#.WyvPLS2ZNp8, 2010. Accessed: 2018-06-21.

[49] Robocode. Robocode. http://robocode.sourceforge.net, 2017. Accessed: 2017-10-03.

[50] R. M. Ryan and E. L. Deci. Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, 25(1):54 – 67, 2000.

[51] R. M. Ryan, C. S. Rigby, and A. Przybylski. The motivational pull of video games: A self-determination theory approach. *Motivation and emotion*, 30(4):344–360, 2006.

[52] M. Sailer, J. U. Hense, S. K. Mayr, and H. Mandl. How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69:371–380, 2017.

[53] Z. C. Schreuders and E. Butterfield. Gamification for teaching and learning computer security in higher education. In *2016 USENIX Workshop on Advances in Security Education (ASE 16)*. USENIX Association, Aug. 2016.

[54] J. L. Sherry, K. Lucas, B. S. Greenberg, and K. Lachlan. Video game uses and gratifications as predictors of use and game preference. *Playing video games: Motives, responses, and consequences*, 24(1):213–224, 2006.

[55] SoloLearn. Ruby Tutorial. https://www.sololearn.com/Course/Ruby/, 2018. Accessed: 2018-04-5.

[56] J. Thom, D. Millen, and J. DiMicco. Removing gamification from an enterprise sns. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work*, CSCW '12, pages 1067–1070, New York, NY, USA, 2012. ACM.

[57] A. Topîrceanu. Gamified learning: A role-playing approach to increase student in-class motivation. *Procedia Computer Science*, 112:41–50, 2017.

[58] D. Toth and M. Kayler. Integrating Role-Playing Games into Computer Science Courses as a Pedagogical Tool. In *SIGCSE 2015 - Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, pages 386–391, 2015.

[59] A. Vahldick, A. J. Mendes, and M. J. Marcelino. A review of games designed to improve introductory computer programming competencies. In *Frontiers in Education Conference (FIE), 2014 IEEE*, pages 1–7. IEEE, 2014.

[60] R. J. Vallerand, L. G. Pelletier, M. R. Blais, N. M. Briere, C. Senecal, and E. F. Vallieres. The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, 52(4):1003–1017, 1992.

[61] P. Wilkinson. Why do projects fail? http://www.gamingworks.nl/why-do-projects-fail/, 2012. Accessed: 2017-09-12.

[62] R. Zender, R. Metzler, and U. Lucke. Freshupa pervasive educational game for freshmen. *Pervasive and mobile computing*, 14:47–56, 2014.

Appendices

A COMMAND-LINE HACKER SURVEY

Gaming Questions

1. Typically, how many hours do you spend playing recreational games (computer, console and/or mobile) each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

2. Typically, how many hours do you spend playing board games each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

Puzzle Questions

3. Did you complete any Command-Line Hacker puzzles beyond what was required for course credit?

   (a) Yes. Which ones? _____

   (b) No

   Please indicate how much you agree with the following statements about the Command-Line Hacker puzzles using the below scale:

   1 = Strongly disagree

   2 = Disagree

   3 = Agree

   4 = Strongly agree

4. The puzzles were a good addition to the course

   1 2 3 4

5. I wished we could have done more puzzles in the course

   1 2 3 4

6. The puzzles increased my motivation to learn the topic(s)

   1 2 3 4

7. The puzzle format increased my motivation to complete more puzzles than what was required for course credit

   1 2 3 4

8. What did you like about the puzzles?

9. What didn't you like about the puzzles?

Badges Questions

10. Did you earn any badges?

    (a) Yes. Which ones? _____

    (b) No

    Please indicate how much you agree with the following statements about the Command-Line Hacker badges using the below scale:

    1 = Strongly disagree

    2 = Disagree

    3 = Agree

    4 = Strongly agree

11. The badges were a good addition to the course

    1 2 3 4

12. I wished we could have earned more badges in the course

    1 2 3 4

13. The badges increased my motivation to learn the topic(s)

    1 2 3 4

14. The badges increased my motivation to complete the supplemental exercise(s)

    1 2 3 4

15. What did you like about using badges in Canvas?

16. What didn't you like about using badges in Canvas?

Demographic Questions

Please answer the following demographic questions.

17. Gender _____

18. Ethnicity

    (a) Black or African American; not Hispanic

(b) Hispanic or Latino
(c) Asian
(d) White, Caucasian; not Hispanic
(e) American Indian/Native American
(f) Alaska Native
(g) Native Hawaiian/Pacific Islander
(h) Prefer not to specify
(i) Other (Please specify) ____

19. Ethnicity

20. Level in School

(a) Freshman
(b) Sophomore
(c) Junior
(d) Senior
(e) 1st year masters
(f) 2nd year masters
(g) Other (Please specify) ____

21. Age

(a) 18-24 years old
(b) 25-34 years old
(c) 35-44 years old
(d) 45-54 years old
(e) 55-64 years old
(f) 65-74 years old
(g) 75 years or older

22. GPA

(a) 2.0 or less
(b) 2.1 - 2.5
(c) 2.6 - 3.0
(d) 3.1 - 3.5
(e) 3.6 or higher

B RUBY WARRIOR STUDY SURVEY

Gaming Questions

1. Typically, how many hours do you spend playing recreational games (computer, console and/or mobile) each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

2. Typically, how many hours do you spend playing board games each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

Ruby Warrior Questions

Please indicate how much you agree with the following statements about Ruby Warrior using the below scale:

1 = Strongly disagree

2 = Disagree

3 = Agree

4 = Strongly agree

3. Ruby Warrior was a good addition to the course

   1 2 3 4

4. I wished we could have played more games like Ruby Warrior in the course

   1 2 3 4

5. Ruby Warrior increased my motivation to learn the topic(s)

   1 2 3 4

6. Ruby Warrior increased my motivation to complete more levels than what was required for course credit

   1 2 3 4

7. RubyWarrior increased my motivation to continue to play in subsequent weeks. (**Spring 2018**)

   1 2 3 4

8. The leaderboard increased my motivation to complete more levels than was required for course credit. (**Spring 2018**)

   1 2 3 4

9. The leaderboard increased my motivation to continue to play RubyWarrior in subsequent weeks. (**Spring 2018**)

   1 2 3 4

10. What did you like about Ruby Warrior?

11. What didn't you like about Ruby Warrior?

12. Why did you stop at the level that you did? (**Spring 2018**)

13. Did you complete any RubyWarrior levels beyond what was required for course credit?

    (a) Yes. How many levels? _____

    (b) No

14. Why did you continue past the required levels? (**Spring 2018**)

Demographic Questions

Please answer the following demographic questions.

15. Gender _____

16. Ethnicity

    (a) Black or African American; not Hispanic

    (b) Hispanic or Latino

    (c) Asian

    (d) White, Caucasian; not Hispanic

    (e) American Indian/Native American

    (f) Alaska Native

    (g) Native Hawaiian/Pacific Islander

    (h) Prefer not to specify

    (i) Other (Please specify) _____

17. Ethnicity

18. Level in School

    (a) Freshman

    (b) Sophomore

(c) Junior

(d) Senior

(e) 1st year masters

(f) 2nd year masters

(g) Other (Please specify) _____

19. Age

(a) 18-24 years old

(b) 25-34 years old

(c) 35-44 years old

(d) 45-54 years old

(e) 55-64 years old

(f) 65-74 years old

(g) 75 years or older

20. GPA

(a) 2.0 or less

(b) 2.1 - 2.5

(c) 2.6 - 3.0

(d) 3.1 - 3.5

(e) 3.6 or higher

C CLASSCRAFT STUDENT INFORMATION (ONLINE SECTION)

Introduction

Online courses can be more challenging because students tend to feel isolated and have trouble motivating themselves to keep up with the course deadlines. This semester, in an effort to transform how we all experience this online class, we will be trialling a fantasy-themed game called Classcraft. While your in-game progress will not impact your course grade in any direct way, the activities will be designed to support your learning experience and therefore participation should help you perform better on the graded course content. Please note that we may have to make adjustments as we go along and, to this end, I will be seeking out your ideas and opinions.

Each participating student will choose a character class (warrior, healer, or mage) and will be assigned to a team. You will work together in a team to gain experience points through positive behaviors and academic achievements and will earn rewards that will help you succeed.

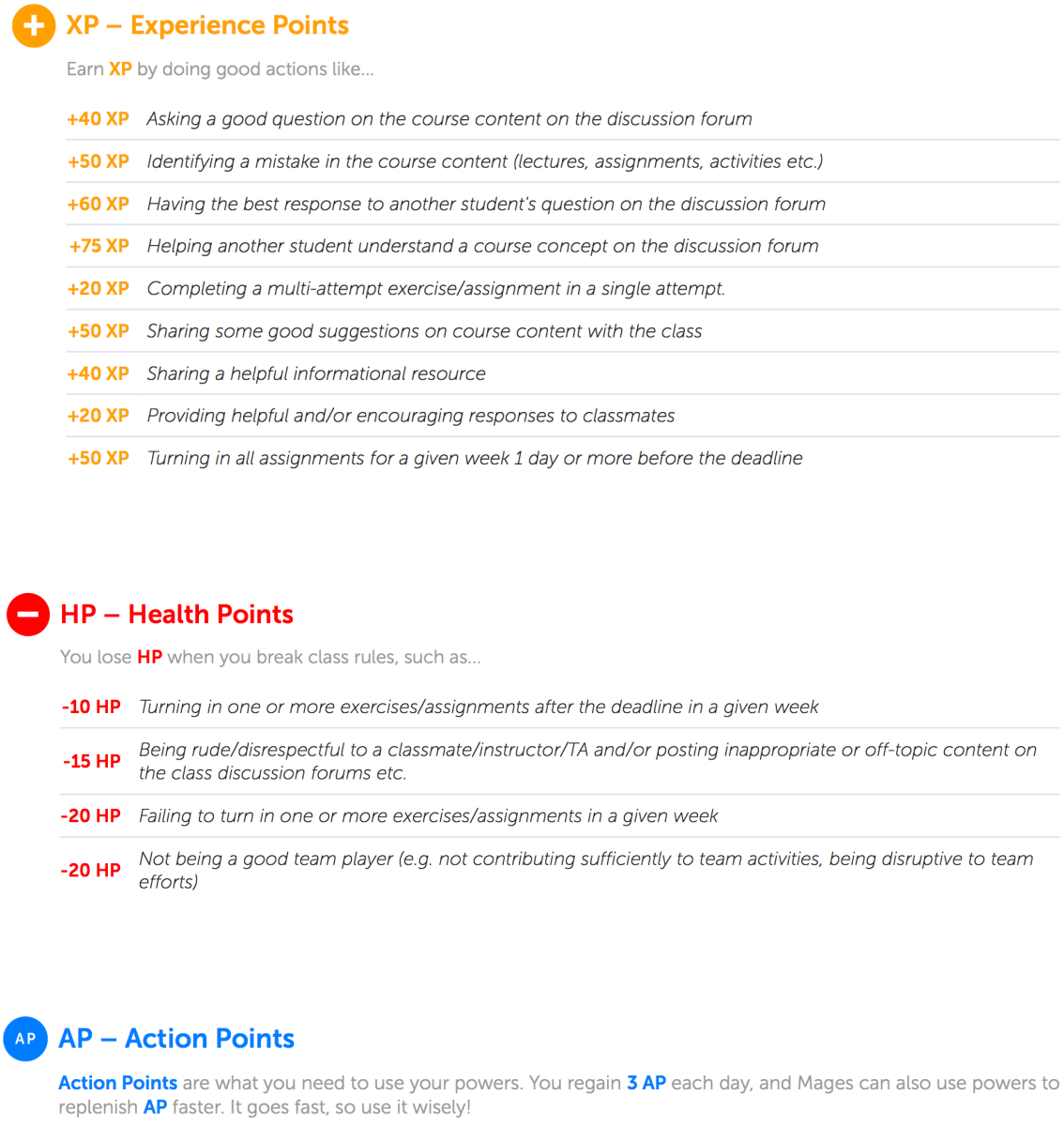
In our class, we will be using this tool to encourage the development of soft skills such as collaboration, punctuality and meeting deadlines as these are skills essential to computing professionals.

Please watch the below video introduction: https://youtu.be/zgcxo3dVcTU

Points

Next week, you'll create a character in the game and will meet your new team. By demonstrating positive behaviors, you'll earn Experience Points (XP) that will allow you to level up and learn new powers. These powers have real benefits for you and your team, so you'll need to work together to succeed! If you fail to be punctual, collaborate positively with teammates or miss deadlines you'll lose Health Points (HP) your life energy in the game and eventually fall in battle if you take

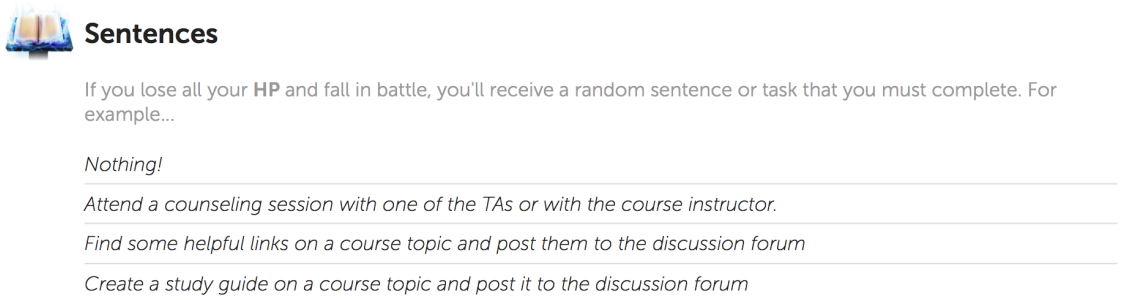
too much damage. When this happens, the rest of your team will take damage, too.



Sentences

If you fall in battle, your team will lose HP and the cursed die will be rolled in game to determine your sentence. You will need to serve your sentence before you will be able to earn XP or use your powers again in the game.

In our class, the sentences are...



Character Classes

There are three character classes to choose from, each with unique powers and stats.

The classes and their attributes are...

Warrior

Warriors are a team's guardian, protecting their teammates from damage (losing HP). They're super strong but can't use their powers as often as other characters.

Mage

Mages are powerhouses! They can use their powers most often, but they have fewer

HP to lose before they fall in battle. Mages replenish Action Points (AP) so their team can use powers as often as possible.

Healer

Healers are the most balanced of the three characters in terms of HP and AP. It's their job to heal their teammates when their health gets low to prevent them from falling in battle (which would cause your team to lose HP!)

Teams

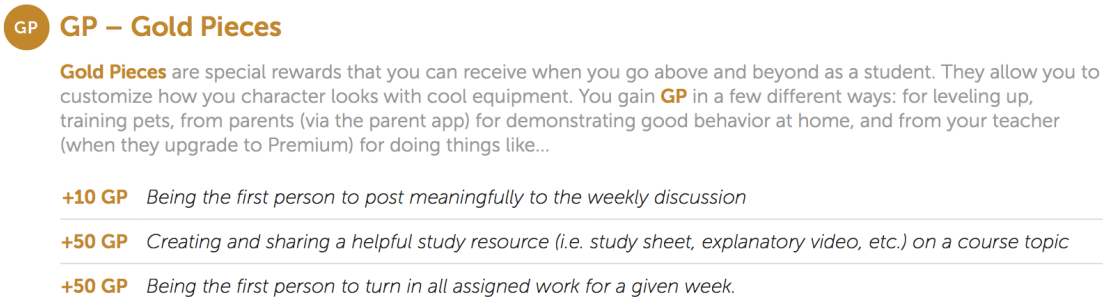
Each team will be comprised of four or five players. During the first week of class, you will complete a survey where you will choose your preferences in terms of character class and will indicate your experience with games and overall interest in this endeavor so that I can balance the teams. Once the teams have been formed, you will participate in a discussion with your teammates to determine a team name and to decide class roles for the members of your team.

Balancing Your Team You will want to be sure your team has at least one Warrior, one Mage and one Healer so you can help each other succeed!

Pro Tip: Choosing a collaborative power (one that helps your team) is a great way to earn extra XP and level up faster!

Gold Pieces

Going above and beyond in class will earn you gold pieces, which can be spent on armor for your avatar and pets that will provide certain boosts for you and your team.

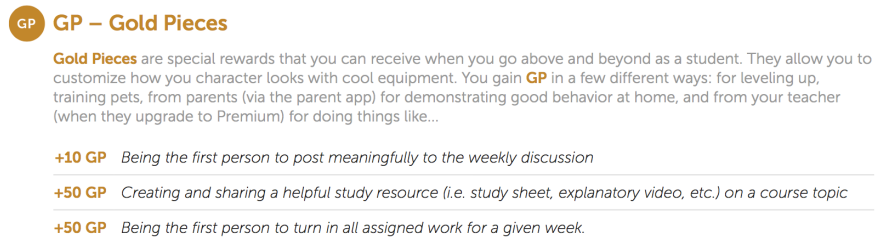


Random Events

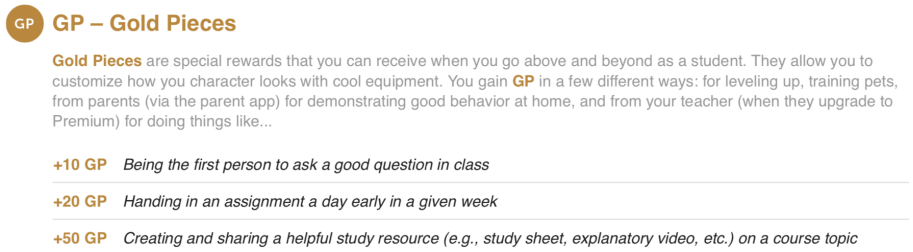
Each week there will be a random event posted that will impact one or more students, teams and/or character classes. These could cause gains or losses in HP, AP and/or XP.

D CLASSCRAFT BEHAVIORS AND POWERS

Positive behaviors in classcraft were rewarded with experience points and gold pieces. See figures 29 and 30. Negative behaviors were penalized with health point deductions. See figure 31. Students could also use character class powers to benefit themselves and their teammates. See figures 32, 33, and 34.

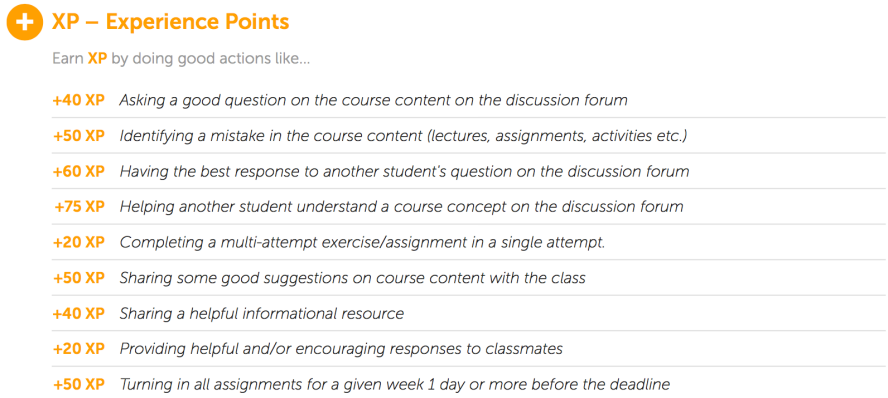


(a) GP - Online Class

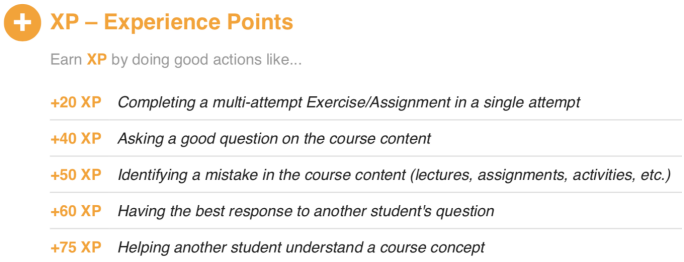


(b) GP - Face-to-Face Class

Figure 29: Classcraft XP Behavior Rewards

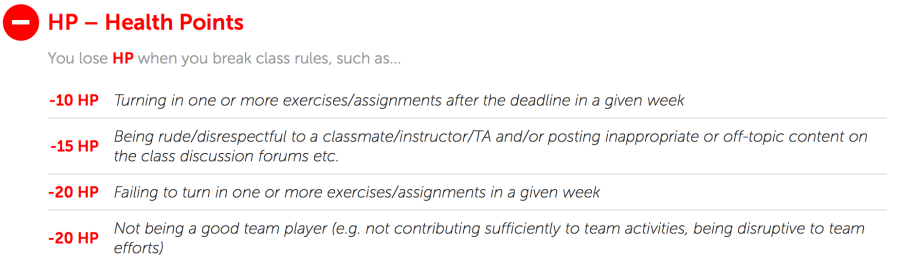


(a) XP - Online Class

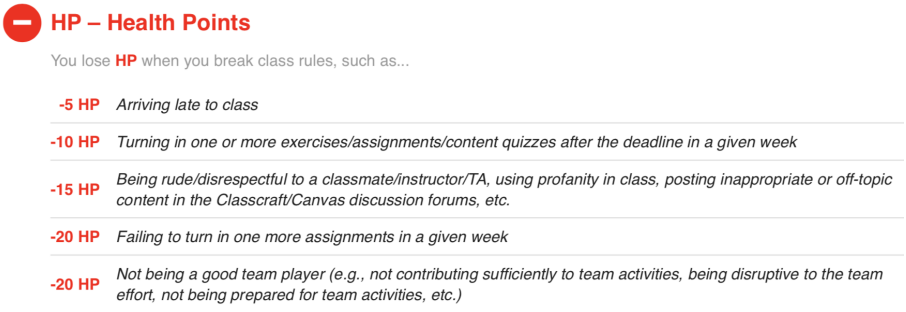


(b) XP - Face-to-Face Class

Figure 30: Classcraft GP Behavior Rewards



(a) HP - Online Class



(b) HP - Face-to-Face Class

Figure 31: Classcraft HP Behavior Penalties

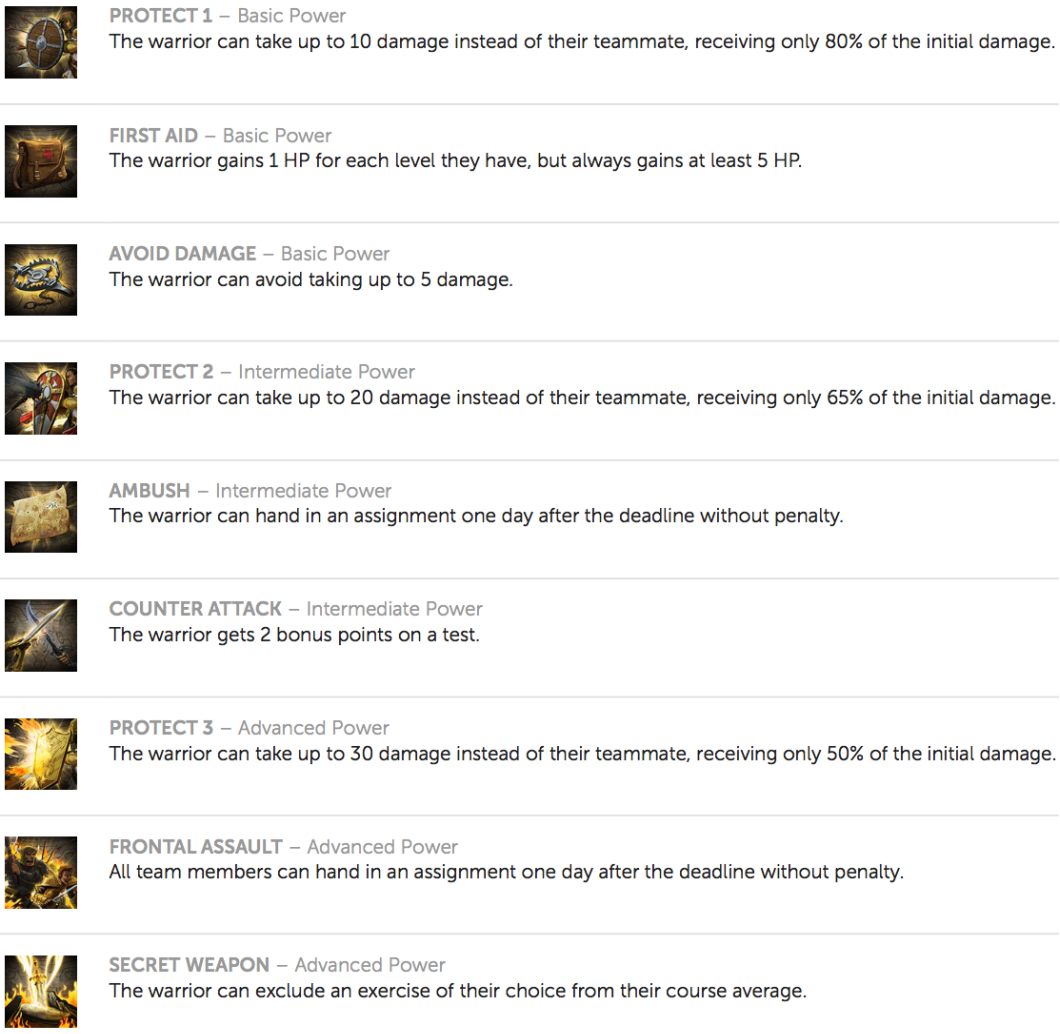


Figure 32: Warrior Powers

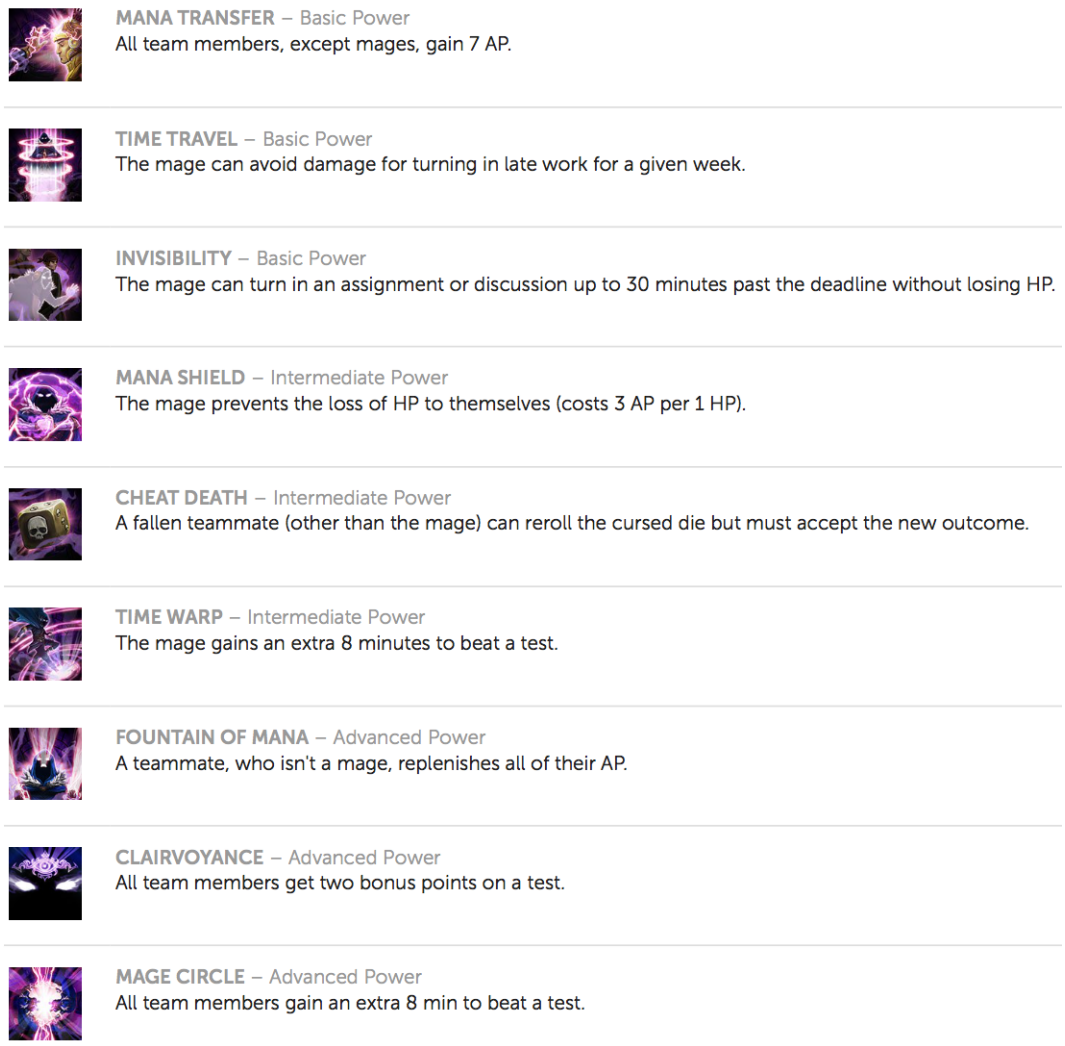


Figure 33: Mage Powers

HEAL 1 – Basic Power
A teammate gains 10 HP.

SAINTHOOD – Basic Power
The healer can extend the deadline of an exercise/assignment for the entire team by 1 hour.

ARDENT FAITH – Basic Power
The healer can have a one day extension on an assignment or exercise.

HEAL 2 – Intermediate Power
A teammate gains 20 HP.

FAVOR OF THE GODS – Intermediate Power
The healer gets 2 bonus points on a test.

REVIVE – Intermediate Power
When a teammate (not including the healer) falls to 0 HP, they avoid all penalties and come back to life with 1 HP.

HEAL 3 – Advanced Power
A teammate gains 30 HP.

HEALING CIRCLE – Advanced Power
All team members, other than the healer, gain 15 HP.

PRAYER – Advanced Power
All team members get two bonus points on a test.

Figure 34: Healer Powers

E CLASSCRAFT SURVEY

Gaming Questions

1. Typically, how many hours do you spend playing recreational games (computer, console and/or mobile) each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

2. Typically, how many hours do you spend playing board games each week?

   (a) None

   (b) More than 0 but less than 3 hours per week

   (c) 3 to 7 hours per week

   (d) Greater than 7 hours per week

Engagement Questions

To what extent to the following behaviors, thoughts, and feelings describe you in THIS COURSE using the below scale:

1 = not at all characteristic of me

2 = not really characteristic of me

3 = moderately characteristic of me

4 = characteristic of me

5 = Very characteristic of me

3. Making sure to study on a regular basis

4. Putting forth effort

   1 2 3 4 5

5. Completing all of the assigned tasks

   1 2 3 4 5

6. Keeping up with the readings and/or videos

   1 2 3 4 5

7. Reviewing course content between classes to be sure I understand the material

   1 2 3 4 5

8. Being organized

   1 2 3 4 5

9. Taking good notes on the course readings and/or videos

   1 2 3 4 5

10. Listening carefully to the recorded videos and/or during class

    1 2 3 4 5

11. Finding ways to make the course content relevant to my life

    1 2 3 4 5

12. Applying course content in my life

    1 2 3 4 5

13. Finding ways to make the course interesting to me

    1 2 3 4 5

14. Thinking about the course between class meetings and/or study sessions

    1 2 3 4 5

15. Really desiring to learn the material

    1 2 3 4 5

16. Raising my hand in class or posting to the course discussion forums

    1 2 3 4 5

17. Asking questions when I dont understand the course content

    1 2 3 4 5

18. Having fun in class or on the discussion forums

    1 2 3 4 5

19. Participating actively in-class group discussions or in the course discussion forums

    1 2 3 4 5

20. Going to the Teaching Assistants or Professors office hours to review assignments/tests or to ask questions

    1 2 3 4 5

21. Helping fellow students

    1 2 3 4 5

22. Getting a good grade

    1 2 3 4 5

23. Doing well on the tests and assigned tasks

    1 2 3 4 5

24. Being confident that I can learn and do well in class

    1 2 3 4 5

Please answer the below questions about the course in general.

25. How engaged were you in this class? (1= not at all engaged, 6 = extremely engaged)

    1 2 3 4 5 6

26. How engaged were you in this class compared to the other courses youve taken this semester? (1 = less engaged than in any of my other courses, 6 = more engaged than in any of my other courses)

    1 2 3 4 5 6

27. If I had to choose between getting a good grade and being challenged in class, I would choose:

    (a) good grade

    (b) being challenged

Classcraft Questions

Please indicate how much you agree with the following statements about Ruby Warrior using the below scale:

1 = Strongly disagree

2 = Disagree

3 = Agree

4 = Strongly agree

28. Classcraft was a good addition to the course

    1 2 3 4

29. I wished more of the activities in the course had associated Classcraft rewards

    1 2 3 4

30. Classcraft rewards increased my motivation to collaborate with my team- or classmates on course materials

    1 2 3 4

31. Classcraft rewards increased my motivation to turn in my work ahead of deadlines

    1 2 3 4

32. Classcraft rewards increased my motivation to raise my hand in class or to participate in the discussion forums.

    1 2 3 4

33. Classcraft rewards increased my motivation to help other students

    1 2 3 4

34. What did you like about Classcraft?

35. What didnt you like about Classcraft?

36. Were there any ways that Classcraft negatively impacted your experience and/or motivation in this class?

37. Do you have any suggestions for rewards, powers etc. in Classcraft that would enhance your experience?

38. How much Classcraft XP did you earn this semester?

    (a) Less than 100
    (b) 100 599
    (c) 600 1099
    (d) 1100 1599
    (e) 1600 2199
    (f) ¿= 2200

39. How much Classcraft XP did you earn this semester?

    (a) I did not use powers at all
    (b) A few times during the semester
    (c) 1 - 3 times per month
    (d) 1 - 2 times per week
    (e) 3 times or more per week

Demographic Questions

Please answer the following demographic questions.

40. Gender _____

41. Ethnicity

    (a) Black or African American; not Hispanic
    (b) Hispanic or Latino
    (c) Asian

(d) White, Caucasian; not Hispanic
(e) American Indian/Native American
(f) Alaska Native
(g) Native Hawaiian/Pacific Islander
(h) Prefer not to specify
(i) Other (Please specify) _____

42. Ethnicity

43. Level in School

(a) Freshman
(b) Sophomore
(c) Junior
(d) Senior
(e) 1st year masters
(f) 2nd year masters
(g) Other (Please specify) _____

44. Age

(a) 18-24 years old
(b) 25-34 years old
(c) 35-44 years old
(d) 45-54 years old
(e) 55-64 years old
(f) 65-74 years old
(g) 75 years or older

45. GPA

(a) 2.0 or less
(b) 2.1 - 2.5
(c) 2.6 - 3.0
(d) 3.1 - 3.5
(e) 3.6 or higher

F PARTICIPATION POINT SURVEY

Engagement Questions

To what extent to the following behaviors, thoughts, and feelings describe you in THIS COURSE using the below scale:

1 = not at all characteristic of me
2 = not really characteristic of me
3 = moderately characteristic of me
4 = characteristic of me
5 = Very characteristic of me

1. Making sure to study on a regular basis
2. Putting forth effort

   1 2 3 4 5
3. Completing all of the assigned tasks

   1 2 3 4 5
4. Keeping up with the readings and/or videos

   1 2 3 4 5
5. Reviewing course content between classes to be sure I understand the material

   1 2 3 4 5
6. Being organized

   1 2 3 4 5
7. Taking good notes on the course readings and/or videos

   1 2 3 4 5
8. Listening carefully to the recorded videos and/or during class

   1 2 3 4 5
9. Finding ways to make the course content relevant to my life

   1 2 3 4 5
10. Applying course content in my life

    1 2 3 4 5
11. Finding ways to make the course interesting to me

    1 2 3 4 5
12. Thinking about the course between class meetings and/or study sessions

    1 2 3 4 5

13. Really desiring to learn the material

    1 2 3 4 5

14. Raising my hand in class or posting to the course discussion forums

    1 2 3 4 5

15. Asking questions when I dont understand the course content

    1 2 3 4 5

16. Having fun in class or on the discussion forums

    1 2 3 4 5

17. Participating actively in-class group discussions or in the course discussion forums

    1 2 3 4 5

18. Going to the Teaching Assistants or Professors office hours to review assignments/tests or to ask questions

    1 2 3 4 5

19. Helping fellow students

    1 2 3 4 5

20. Getting a good grade

    1 2 3 4 5

21. Doing well on the tests and assigned tasks

    1 2 3 4 5

22. Being confident that I can learn and do well in class

    1 2 3 4 5

    Please answer the below questions about the course in general.

23. How engaged were you in this class? (1= not at all engaged, 6 = extremely engaged)

    1 2 3 4 5 6

24. How engaged were you in this class compared to the other courses youve taken this semester? (1 = less engaged than in any of my other courses, 6 = more engaged than in any of my other courses)

    1 2 3 4 5 6

25. If I had to choose between getting a good grade and being challenged in class, I would choose:

    (a) good grade

    (b) being challenged

Participation Point Questions

Please indicate how much you agree with the following statements about Participation Points using the below scale:

1 = Strongly disagree

2 = Disagree

3 = Agree

4 = Strongly agree

26. Participation points were a good addition to the course.

    1 2 3 4

27. I wished more of the activities in the course counted toward my participation points

    1 2 3 4

28. Participation points increased my motivation to collaborate with my team- or classmates on course materials

    1 2 3 4

29. Participation points increased my motivation to turn in my work ahead of deadlines

    1 2 3 4

30. Participation points increased my motivation to raise my hand in class or to participate in the discussion forums

    1 2 3 4

31. Participation points increased my motivation to help other students

    1 2 3 4

32. What did you like about participation points?

33. What didnt you like about participation points?

34. Were there any ways that participation points negatively impacted your experience and/or motivation in this class?

35. Do you have any suggestions that would enhance your experience of earning participation points?

36. How often did you engage in activities to earn participation points?

    (a) I did not engage in activities that earned participation points at all

    (b) A few times during the semester

(c) 1 - 3 times per month

(d) 1 - 2 times per week

(e) 3 times or more per week

Demographic Questions

Please answer the following demographic questions.

37. Gender _____

38. Ethnicity

    (a) Black or African American; not Hispanic

    (b) Hispanic or Latino

    (c) Asian

    (d) White, Caucasian; not Hispanic

    (e) American Indian/Native American

    (f) Alaska Native

    (g) Native Hawaiian/Pacific Islander

    (h) Prefer not to specify

    (i) Other (Please specify) _____

39. Ethnicity

40. Level in School

    (a) Freshman

    (b) Sophomore

    (c) Junior

    (d) Senior

    (e) 1st year masters

    (f) 2nd year masters

    (g) Other (Please specify) _____

41. Age

    (a) 18-24 years old

    (b) 25-34 years old

    (c) 35-44 years old

    (d) 45-54 years old

    (e) 55-64 years old

(f) 65-74 years old

(g) 75 years or older

42. GPA

(a) 2.0 or less

(b) 2.1 - 2.5

(c) 2.6 - 3.0

(d) 3.1 - 3.5

(e) 3.6 or higher

G COURSE INFORMATION

ITSC 3146: Introduction to Operating Systems and Networking

Course Catalog Description

ITSC 3146: Introduction to Operating Systems and Networking (3) - Prerequisite: ITSC 2214. Introduces the fundamentals of operating systems together with the basics of networking and communications. Topics include: processes, thread, scheduling, cache, memory management, file systems, interprocess communication, network architecture and protocols, HTTP, MAC, IP, TCP/UPD, and Internet routing.

Course Objectives

Operating systems and networks are fundamental components of modern technological systems. Today systems can not work in isolation. The operating system is the key software layer that manages the device hardware and the network stack that allows multiple devices to communicate. The aim of this course is to provide computer science undergraduate students with fundamental concepts in operating systems such as process, file and memory management and interprocess communication. Similarly a major aspect of the course is to understand key network components and protocols such as the OSI Model, MAC, IP routing and TCP/UDP, HTTP protocols. Students learn through several hands-on activities how to setup and configure infrastructure focusing on the use of the command line terminals in Linux, writing shell scripts, access control rules as well as configuring common network services such as DNS, SSH and firewalls.

ITSC 3155: Software Engineering

Course Catalog Description

ITSC 3155: Software Engineering (3) - Prerequisite: ITSC 2214. An introduction to software engineering, which advances the study and application of engineering principles, methods, and techniques that can help us to improve the process of creating software as well as the resulting software products. The course covers fundamentals of software engineering, including: modern software process models; eliciting, specifying, and evaluating software system requirements; designing software systems to embody required quality attributes, including usability and security; an introduction to reusable software design solutions in the form of software architectural styles and design patterns; software system modeling, implementation, and deployment; and software quality assurance (measurement, inspection, testing). Project planning, working in teams, and using modern software development tools are also explored.

Course Objectives

The aim of this course is to teach the modern techniques, tools and methods of software engineering that are most widely used by the worlds leading software companies. To this end, this course is set up so students learn by applying each concept taught through hands-on examples using Ruby and Ruby on Rails. While the Agile methodology will be applied in this course, plan and document methodologies (ie - waterfall) will be discussed so students learn to identify which approach is appropriate

for a given scenario.

H IRB 17-0025

OFFICE OF RESEARCH COMPLIANCE
9201 University City Boulevard
319 Cameron Hall
Charlotte NC 28223-0001
(704)-687-1871
Web site: http://research.uncc.edu/
Federalwide Assurance (FWA) #00000649

To: Stacey Watson
Software and Information Systems

From: IRB

Date: 2/07/2017
RE: Notice of Approval of Exemption
Exemption Category: 1.Educational setting,2.Survey, interview, public observation
Study #: 17-0025

Study Title: Motivating students to develop co-curricular computing skills through gamification

This submission has been reviewed by the IRB and was determined to meet the Exempt category cited above under 45 CFR 46.101(b).

This determination will expire one year from the date of this letter. It is the Principal Investigator's responsibility to submit for renewal of this determination. You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented.

Study Description:
We seek to understand whether gamification elements, specifically badges and/or puzzles, can motivate students to engage in learning activities that do not count toward their course grade.In this study we will evaluate the use of badges and a puzzle in two specific courses, where these elements are already in use. We will evaluate their impact on motivating students to complete activities that go beyond what is assigned for course grades. We will also gather student perceptions of the badges and puzzle in these courses.

Investigator's Responsibilities:
It is the investigator's responsibility to promptly inform the committee of any changes in the proposed research, and of any adverse events or unanticipated risks to participants or others. You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented.

If applicable, your approved consent forms and other documents are available online at http://uncc.myresearchonline.org/irb/index.cfm?event=home.dashboard.irbStudyManagement&irb_id=17-0025.

Data security procedures must follow procedures as approved in the protocol and in accordance with ITS Guidelines for Data Handling and the End User Checklist.

Please be aware that approval may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records).

CC:
Heather Lipford, Software and Information Systems

I IRB 17-0320

OFFICE OF RESEARCH COMPLIANCE
9201 University City Boulevard
319 Cameron Hall
Charlotte NC 28223-0001
(704)-687-1871
Web site: http://research.uncc.edu/
Federalwide Assurance (FWA) #00000649

To: Stacey Watson
Software and Information Systems

From: IRB

Date: 9/15/2017
RE: Notice of Approval of Exemption
Exemption Category: 1.Educational setting
Study #: 17-0320

Study Title: Motivating students to Develop Soft Skills with Gamification: Classcraft

This submission has been reviewed by the IRB and was determined to meet the Exempt category cited above under 45 CFR 46.101(b).

This determination will expire one year from the date of this letter. It is the Principal Investigator's responsibility to submit for renewal of this determination. You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented.

Study Description:

We seek to understand whether a gamification tool called Classcraft can motivate students to develop and practice soft skills such as collaboration, punctuality, and meeting deadlines.
In this study, we will evaluate the use of Classcraft in two specific courses. We will evaluate its impact on motivating students to develop their soft skills. We will also gather student perceptions of the tool in these courses.
Investigator's Responsibilities:
It is the investigator's responsibility to promptly inform the committee of any changes in the proposed research, and of any adverse events or unanticipated risks to participants or others. You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented.

If applicable, your approved consent forms and other documents are available online at http://uncc.myresearchonline.org/irb/index.cfm?event=home.dashboard.irbStudyManagement&irb_id=17-0320.

Data security procedures must follow procedures as approved in the protocol and in accordance with ITS Guidelines for Data Handling.

Please be aware that approval may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records).

CC:
Julio Bahamon, Computer Science
Heather Lipford, Software and Information Systems
Harini Ramaprasad, Computer Science