TINGLE – TOPIC-INDEPENDENT GAMIFICATION

LEARNING ENVIRONMENT

By

CHRIS LOREN CAIN

A dissertation submitted in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
School of Electrical Engineering and Computer Science

JULY 2018

To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation of CHRIS LOREN CAIN find it satisfactory and recommend that it be accepted.

Matthew E. Taylor, Ph.D., Chair

Shira Broschat, Ph.D.

Anne Anderson, Ph.D.

ACKNOWLEDGEMENT

I would like to acknowledge my advisor, Dr. Matthew E. Taylor, for his support throughout my graduate education. His insight and guidance have helped me reach this point. Additionally, I would like to acknowledge Dr. Shira Broschat and Dr. Anne Anderson for their support on my committee. Their support has ensured I’ve always had a classroom to deploy my research, and their willingness to work with me has helped this research reach this point. Finally, I would like to acknowledge Dr. Olusola Adesope for his support through my job search and his dedication organizing the programming camps we’ve run the last couple years.

TINGLE – TOPIC-INDEPENDENT GAMIFICATION

LEARNING ENVIRONMENT

Abstract

by Chris Loren Cain, Ph.D.
Washington State University
July 2018

Chair: Matthew E. Taylor

Motivating student commitment and engagement in learning, using gamification, or games embedded in non-game settings, has been sought after by game researchers, game designers, academic content developers, and instructors alike. With the rise of free-to-play mobile and casual games, games have become more accessible than ever, leading to greater opportunity to understand player engagement motivations. Developing an accurate understanding of diverse player motivations will allow games not as intrinsic motivators, but rather as extrinsic effort/reward motivators with the resolution to target individual preferences. Given the rise in casual gaming popularity, developing methodology for enhancing student motivation and engagement in class by employing casual games played outside of class, but with effort-based rewards tied to academic engagement, will become a more effective tool as player preference research evolves. In this dissertation, I propose and validate methodology using existing player type research. This methodology leverages aspects of psychology research in motivation and personality theory, and is capable of leveraging advances in smart health technology, to create effort-based student evaluation techniques to map effort to game progress across numerous

disciplines, subject material, and ages. This allows students to play one game outside of class, with mechanics based on their own game preferences, where the main progression is achieved through academic effort applied during and outside of class.

This technique offers several benefits over existing gamification approaches. By building a model with instructor involvement flexibility as well as student preferences, the result is adaptable to diverse curricula, teaching styles and classroom atmospheres across all ages.

My research will proceed as follows: I use a simple game and approach to determine the baseline motivation for a game played outside of class with no effort-based ties to class. I then use a single tie to class and a game designed around specific game preferences to determine the extent students with specific game mechanic preferences find this system motivating. Next, I explore the validity of using player typology to predict game preferences and explore generalizability. Finally, I design a game with wider-reaching appeal and multiple effort-based ties back to class to validate TINGLE's design.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

The goal of my research is to motivate and engage students during class such that we see increases in their learning and retention, regardless of differences in current performance ability. Gamification, or the use of gaming elements in non-game settings such as the classroom, is becoming a popular method of engaging students in the learning process. Keeping students engaged and focused on class material increases retention of key concepts, increases student connection to the classroom [1], and enhances students' socioemotional growth [2], ultimately leading to greater mastery of disciplinary content [3]. While this approach has been successful in other areas, such as industry, this work focuses on formal education environments. Most previous classroom gamification has focused on teaching disciplinary content in the classroom through the use of games or game mechanics designed to be enjoyable to students in order to increase accessibility and to provide increased motivation for students as they learn the disciplinary content. However, a number of limitations in current techniques have led to the need for additional gamification methods.

Topic-INdependent Gamification Learning Environment (TINGLE) is designed to incentivize students to complete course material using gaming elements, similar to "traditional" gamification, by tying games directly to course content. However, TINGLE uses an alternative approach to traditional gamification in that each student's progress in the classroom is mapped to progress in a game independent of course material and situated *outside* of the classroom.

Current students in the US have been brought up in a world of games for leisure, and more than 150 million Americans play video games [5]. By creating a game similar to games familiar to students, there is a low barrier to entry. The goal of this project is to award game progress based on effort-based class assessments such as attendance, homework/lab completion, and individual student grade trends. By tying progression in the game to a student's progress in class, the student may find the class more relatable, as their actions in class influence a game with familiar mechanics. The gamified class may also motivate students to engage with more challenging content. Students having positive experiences with giving increased effort on tasks and overcoming challenges can lead to improved persistence and increase the likelihood of engagement in the class.

Based on this goal, my research hypotheses for this dissertation are as follows:

- A student playing a content-independent game, outside of class, but with ties back to curricular effort, will experience increases in self-reported motivation and engagement in class, as well as an increase in grades.
- The BrainHex player typology can be used to predict the subset of games or minigames students will desire to engage with as well as the length of time students remain engaged with these games.

In order to address these hypotheses, my work proceeds through four studies:

- The pilot study was designed to determine the baseline effect of deploying a game to students in a class, but having them play the game outside of class. The game had no course material embedded and no ties to class, although measures were taken to cap the amount of time students could engage with the game.

- A follow up game, Runecrafters, was developed with the help of five undergraduates and deployed the following year. This study aimed to test whether the game, made for only a couple player types, could motivate and engage students who displayed interest in similar mechanics based on a player typology survey.
- Based on the results of Runecrafters' deployment, another batch of undergraduates and I worked on a game with a tiered architecture. Progress in an overarching game led to progress in one or more minigames, and playing those minigames led to progress in the overarching game. This architecture was designed such that each minigame could be designed for a particular player type, and I could increase the number of students interested in playing my game without dramatically increasing the complexity of the game code.
- Simultaneous to development of the tiered architecture game, I ran a study to determine if the BrainHex player typology could be used to predict player preferences in games played independent of a classroom atmosphere. The goal of this study was to validate the BrainHex typology when predicting games students would like, hopefully leading to the development of a recommendation engine for students who may not know what kinds of games they like. This would increase the accessibility of my gamification system to more students.

1.1 MOTIVATION

The motivation for TINGLE comes from my own personal desire to maximize my motivation when I am doing something I may not be naturally motivated to do because there are times in everyone's life they need to buckle down and make progress on tasks they would rather avoid. As a young student, I, like many others, struggled with the motivation to learn when the material was not something that immediately interested me. This got me thinking about how to craft an intervention. Children often do not know or care about the long-term consequences of their decisions, and there is not always a knowledgeable parent or instructor around to guide their development. I decided what would have helped me would have been to receive something I did care about in the short-term as a reward for prioritizing my development. I was searching for an intrinsic reward, or something I do solely because I like it and not for an external reason, to use as an extrinsic reward, or something I do for an external factor. This is important because classroom learning is not intrinsically motivating to many students, especially as they age [70], leading to the need for some form of external reward to motivate those students to have the best chance they can to succeed because they may not prioritize their future without external help. Learning begins with focus and motivation [70]. Without them, the student has no way to take in information or retain it for later use.

Games were chosen as the external motivator for TINGLE because they are so popular and accessible now. 150 million Americans play games, and gamification has been shown to be an effective way to increase motivation and engagement in class[20,30,32,34,37-42]. With the rise of mobile gaming, people can play games in short stints on their phones when they are transitioning between tasks or as a break from work. Mobile gaming has become accessible through the use of a free-to-play microtransaction-based model where players can pay to make progress in the game, either directly or by watching advertisements. However, the lack of an initial cost to download and play the game allows companies to reach customers they would not have been able to with a pay-to-play model.

1.2 SUMMARY OF DISSERTATION

There are two major components to this dissertation. The first involves three user studies in construction management/civil engineering and computer science classrooms aimed at determining if a content-independent game deployed outside the classroom, but with ties back to curricular effort, can be used to influence student motivation and engagement in class. This is accomplished by establishing a baseline motivation and engagement level for a content-independent game with no ties to curricular effort, then slowly introducing those ties, determining the effect of each. It is also important to determine if there are any side effects to deploying a content-independent game such that student attention is drawn to the game at the expense of classroom-focused effort. This is explored in more detail in chapters 3 through 5.

The other major component of this dissertation is an analysis of a current player typology method in the above context. I look at BrainHex's ability to predict what games college-age students will like outside of the classroom atmosphere, with the goal of being able to provide game recommendations to students who may not know what kinds of games they like such that improvements to student motivation and engagement through TINGLE can be expanded to include as many students from as many backgrounds as possible.

Chapter 2 explores background work related to gamification, especially in the classroom setting, as well as player typology from both psychology and gaming perspectives.

Chapter 3 introduces the methodology behind TINGLE's development, including the vision and validation behind the decisions.

Chapter 4 describes my pilot study, which establishes a baseline motivation for a content-independent game with no ties to curricular effort. In addition, I discuss the limitations of this study and the lessons learned that were applied to future studies.

Chapter 5 describes the deployment of Runecrafters, TINGLE's first iteration, and the associated study, including TINGLE's first tie back to curricular effort, the daily login code. I also discuss the limitations of this study and lessons learned that were applied to TINGLE's current iteration.

Chapter 6 introduces TINGLE's current iteration, a tiered game that attempts to be accessible and fun to a wider audience, as well as a number of new ties back to curricular effort, including homework submission, lab attendance and submission, and grade trends.

Chapter 7 introduces my study analyzing the BrainHex player typology in the context of game recommendation. I determine the extent to which BrainHex can be used to predict how much a student wants to continue playing a game after a 10-minute play session, as well as the extent to which this prediction algorithm generalizes to unseen games and unseen participants.

1.3 OVERVIEW OF GAMES DEVELOPED

In order to better understand the ties between games and curricular effort, it is important to understand the games that were developed and the decisions behind their mechanics. In this section I will give a brief overview of the three games that were developed for the user studies in chapters 4 through 6.

1.3.1 Pilot Study Game

For my pilot study, I implemented a simple combat- and progression-focused Role Playing Game (RPG). An RPG is a genre in which players assume the roles of characters in a fictional setting. Upon logging into the game, students were able to move their protagonist around the 2D map and interact with monsters present on the map. Upon running into a monster, a fight was initiated with one or more monsters. Players have stats such as life and attack, as do monsters. Combat is turn-based, where the player and monsters take turns attacking. As the player defeats monsters, they gain experience and level up, giving them upgrade points, which they can spend on life, damage, and a difficulty boost, increasing the number and power of monsters they encounter. This is important because players are limited to 5 fights per day in order to limit student interaction with the game so they can focus on other aspects of their life, like doing their homework, socializing, or sleeping. By increasing the number and power of monsters, players increase their experience gain per fight, allowing for faster long-term progress, but they need to be careful or they will occasionally run into fights that are too difficult, their protagonist is defeated, and no experience is awarded.

These mechanics were developed because I wanted to minimize the amount of time students would engage with the game while maximizing their desire to interact with the game.

With these mechanics, students with certain game preferences, such as the desire to create and achieve their own achievements or those motivated to conquer content that was previously difficult or impossible, would find familiar mechanics in a different setting from previous games. However, the game had no story, as development time was limited.

1.3.2 Runecrafters

As a follow up to my pilot study, Runecrafters was developed by a team of 5 undergraduates and me. In an attempt to better engage students with particular game preferences, Runecrafters is a crafting RPG. Players can move their character around, and in addition to running into monsters, they can explore the map to find hidden areas, items, and recipes, which they can use to craft improvements to their character in the form of weapons, armor, potions that temporarily improve their stats, or potions that heal them in combat. Instead of controlling a single character, players take control of a party of characters, each with unique abilities, but who are also defined by their stats, including strength, dexterity, and vitality. Strength influences the damage they do in combat. Dexterity influences their combat ability cooldown times. Vitality influences their life. Combat in Runecrafters is real-time, and each combat skill has a cooldown. In addition to these stats, by gaining experience characters can level up, acquiring both stat and skill points. Game-defined achievements were also developed to reward players for reaching milestones.

1.3.3 Tiered Game

For my major dissertation project and to be more accessible to students with a wider variety of game preferences, another team of 5 undergraduates and I developed a tiered game. In this context, a tiered game is defined to be a game with major overarching progression goals, but the way in which that progress is gained is open ended and can be gained by playing a number of other games or minigames.

The overarching game was developed to be an incremental game, defined to be a game with gameplay that consists of the player performing simple actions such as clicking on the screen repeatedly ("grinding") to earn currency. In this case, the simple action is the filling of a progress bar. When the progress bar reaches 100%, experience and coins are given to the player. The progress bar can be in one of two modes: passive and active. In passive mode, the progress bar fills up slowly, and upon reaching 100% awards a few passive coins and experience. In active mode, the progress bar fills up much more quickly, awarding more experience, as well as both active and passive coins. Gaining enough experience allows the user to level up. Passive and active coins can be used to purchase upgrades to the progress bar, including rate of experience gain, rate at which the progress bar fills up (in passive or active mode), and number of coins gained per progress bar fill. A stat called active time can be gained by students who show effort in class, which is used to keep the progress bar in active mode. Without active time, the progress bar can only be in passive mode. The progress bar continues to fill while users are offline, allowing them to return to the game with progress since the last time they played. This is meant to be an additional motivator to log in and play the game often. Once users gain 50 levels, they can ascend, granting additional bonuses to experience gain, making each future ascension take less time. In addition, they receive perks in the minigames they are playing. Stamina is another stat earned for classroom effort, which allows students access to the minigames. Students spend stamina for each play attempt of a minigame, similar to traditional arcade games. By showing effort-based progress in class, students are awarded stamina, and can interact with the game. Without stamina, users can only gain progress as if they were offline. Finally, there are usable items that grant temporary bonuses such as increasing the experience gained by the progress bar. By strategically using these items in combination, players can massively increase the progress they receive for short bursts. Students acquire these items through classroom effort.

Students play minigames to progress faster in the incremental, as well as to make progress in the minigame itself. There are currently 3 minigames, with plans for more. The first is an exploration- and story-based game where the player role-plays as a person headed to an interview at a tech company, but who is knocked unconscious and wakes up in a fantasy world. Players then explore trap-infested dungeons to find items, progress the story, and rebuild a city whose inhabitants have mysteriously disappeared. By selling items they find and do not need to a non-player game character, players can gain incremental progress. This creates an optimization problem where players can either keep items they need to better be able to face challenges the game throws at them or sell them for progress. Within dungeons, there are hidden rooms containing especially large piles of loot, but to find them, players must explore more of the dungeon than necessary, exposing them to more traps and testing their character's ability to disarm traps. As the player levels up from disarming traps, they increase their ability to disarm future traps.

The second minigame is a simple Sudoku interface. Sudoku is a traditional puzzle game where players must fill in the numbers 1-9 in each row, column, and 3-by-3 box within a 9-by-9 puzzle, given that some of the numbers are already filled in. Players who like puzzle games can play Sudoku in one of three difficulty levels. The time to complete a puzzle is documented, and depending on the speed of completion, progress in the incremental is rewarded. Hints are available to players who are stuck in the puzzle, but they add to the solution time based on how many hints have been requested for the current puzzle. Many standard Sudoku features are available, including pencil mode, the ability to track information that helps deduce the correct solution without filling in the numbers of the puzzle, and an adaptive timer, which allows the user to show or hide the timer if it motivates or bothers them.

The third minigame is a 2D space shooter, where the player takes control of a small ship that shoots projectiles. The player fights waves of enemies and bosses that increase in difficulty as more are defeated. The player loses when the ship runs out of life, and life is restored between each level. Sometimes while the player is flying around and avoiding projectiles fired by enemies, pickups appear on the screen. If the player flies over these pickups before they time out, a number of passive and active coins are awarded in the incremental. By defeating bosses, players can acquire new guns for their ship, which can fire different numbers of projectiles in different patterns and deal variable damage based on the quality of the gun. Players can collect guns and determine which ones are most effective against certain foes.

Two additional minigames are currently being developed. One is an extension of the puzzle style game, with implementations of Kakuro and a sliding block puzzle being developed. The other is a fast-moving falling game, where players avoid obstacles and collect powerups while experiencing the thrill of tumbling toward the ground. The ties between these two minigames and the incremental are still being developed.

Players have the option of playing any one or more minigames in the amounts they choose. By designing simple minigames, and by tying progress in the minigames to progress in the incremental and vice versa, there are a number of mechanics that appeal to different game preferences, without needing to develop an individual game for each different preference.

1.4 CONCLUSION

This dissertation introduces TINGLE as a research instrument designed to create a motivating cycle between an accessible game students play outside of class and the effort they produce in class and on their coursework as well as determine specific students' motivations such that gaming elements and reward structures can be customized for each student to achieve maximum benefit. By the end of this research, the following questions will have been investigated:

- Can a currently existing player typology survey be used to predict which games are liked/disliked by students?
- Given that a student likes a particular game, can that game be used to enhance self-reported motivation and engagement in a classroom setting by tying effort-based progress in the class to progress in the game? Does this have any measurable effect on the students' grades?

CHAPTER 2: BACKGROUND AND RELATED WORK

2.1 INTRODUCTION

Gamification has a rich history of development and deployment in a number of settings, including classrooms, the workplace, self-improvement, and sales. The main use of gamification is to provide an extrinsic motivator such that people have additional motivation to engage in something they may not be intrinsically motivated to engage in [71]. As an example, the mobile app HabitRPG [61] is a game designed to help a person implement and continue practicing healthy habits. The player takes the role of a fantasy character engaging in battles. In order to gain experience, the player must set up tasks such as drinking water or exercising. By marking these items as complete, the in-game character gains experience and can level up. This provides additional incentive to engage with healthy activities, and can lead to the development of healthy habits.

Workplaces have struggled to motivate their employees to produce consistently high quality work, especially in a system that may not provide enough incentive for truly maximizing productivity [72]. Employees may only work hard enough to avoid being fired because they take home the same paycheck regardless of whether they work harder. Even if additional monetary incentive is given, some employees' utility functions will determine the monetary gain is not worth the additional effort required to obtain the bonus. By turning the workplace into a game, employees can be playing a game with or against their coworkers, which may provide additional incentive to work harder and potentially reduce the stress of the work. One such application is Picnic Baskit [62], a community and workplace gamification application. It uses community engagement tools such as contests and social activities to motivate participants to engage with their points, leaderboards, badges, and achievements.

2.2 GAMIFICATION IN THE CLASSROOM

The main background work related to this dissertation is in the field of classroom gamification, which can be broken down into two main subsections:

- Commercial classroom gamification applications, which aim to sell their gamification platform, ease-of-use tools, and classroom integration to create an atmosphere of learning and fun.
- Academic classroom gamification studies, which are not-for-profit experiments, occasionally pushing the boundaries of current gamification knowledge or applying existing ideas in new settings.

This section will give an overview of both of these existing literature types and some commentary on the limitations of the current direction of this field.

2.2.1 COMMERCIAL CLASSROOM GAMIFICATION

Currently, the most popular choice for K-12 commercial classroom gamification is Classcraft, a Role Playing Game developed in 2013, with a beta and first release in 2014. As of July 2017, Classcraft has 2.5 million users and is available in 10 languages [25]. Its popularity stems from its ease-of-use and generalizability, as well as accessibility, as it is free for instructors. Classcraft allows instructors to customize their lectures by integrating them into quests, as students take on the role of adventurers in a choose-your-own-adventure style game. By exploring a map, students interact in teams with learning activities planned by the instructor, earning points when good behavior is displayed that allow them to customize their character and become stronger, either through buying new armor, leveling up, acquiring pets, or regaining lost hit points from battle or bad behavior. There are built-in tools allowing for the creation of random events, timers, and boss battles, as well as analytics and parent communication [26].

There have been attempts to determine the effectiveness of Classcraft in various settings. Studies have shown that Classcraft can foster stronger student collaboration and encourage better behavior [28-29]. However, in one study of 30 students in high school, although engagement with the classroom increased, performance did not [27].

Development of commercial classroom gamification applications is currently ongoing, as the research is still being developed. A gamification approach that utilizes students' own gaming preferences and individual progress has yet to be developed.

2.2.2 CLASSROOM GAMIFICATION STUDIES

There has been growing support within the gamification literature that intrinsic motivation, or motivation that drives one to do something because the activity itself is rewarding, produces greater satisfaction and greater results than does extrinsic motivation, or motivation to do something for an external reward [6,7]. However, Ziechermann points out that intrinsic motivation can be unreliable and variable, making it difficult to create an environment that is always intrinsically motivating, as well as that gamification designers should consider both intrinsic and extrinsic rewards [8]. A further issue with intrinsic rewards in a group setting such as a classroom is that each individual within the group will have different intrinsic motivators, and it will be difficult, if not impossible, to design a setting where each person is intrinsically motivated by gamification within the classroom. Ziechermann asserts that the goal of successful gamification is to create intrinsically motivating extrinsic motivation. One long-term goal of TINGLE is to implement and test such a setting.

There are many useful gamification elements that have results showcasing their effectiveness at increasing motivation and engagement in a classroom setting. The following describes some of the more popular elements:

- Points: Collected as a measure of success or achievement, points can come in a variety of forms. Experience points are acquired to increase the power of a player character. After enough have been acquired, the player character "levels up," getting stronger and learning new abilities. Other forms of points act like currency, where the student can spend them on digital or real-life benefits, including further progress in other game mechanics or a longer recess.
- Levels: Often the way to denote progress through the game, levels are the "chapters" of game design. By completing a level, students may show completion of certain learning content or having reached a threshold in the story. While earlier levels are often easier and shorter, easing the student into the game mechanics, later levels can be longer and more challenging, allowing challenge and difficulty for those who are prepared for it. Good level design allows students to find a level of game difficulty appropriate to their current skills and abilities.

- Badges/achievements: These represent milestones in learning or gameplay and are often displayed on a profile or handed out as physical goods. This reward for task accomplishment can further motivate and engage users for future game and learning content. For those socially or competitively minded, it also serves as a method of progress comparison or display. The ability to display your badges or achievements can be motivating to certain people.
- Leaderboards: For the competitively-minded gamer, leaderboards are another method of comparing your progress to others. This display of level, score, or point accumulation is an incentive to try harder. By succeeding at the leaderboard task, one can rank higher, potentially leapfrogging rivals or maintaining your position.
- Prizes/rewards: Much research has gone into determining the timing and scale of rewards to maximize current and future user motivation and engagement, and research has shown that well-designed rewards are an effective motivator [32]. Multiple smaller progress-based rewards may often be more motivating than a single large reward. Players may feel overwhelmed with the work required to achieve the large reward, and many students have large discount factors, meaning if the nearest reward is too far away, the motivating factor will be greatly diminished. These can be either in the form of physical or digital rewards. While physical rewards have a per-reward cost, digital rewards can be given out at will, allowing students the opportunity to receive rewards more often without additional financial burden.
- Progress bars: Rather than a binary completed/not completed for tasks, achievements, or rewards, progress bars allow students and researchers to visualize progress toward the

goal. It can be motivating to see this progress bar incrementally grow with knowledge that the space left to fill is smaller.

- Story/plot: Good games are more than numbers and often tell a story to engage users, giving them additional incentive to engage with other game mechanics. By completing levels, reaching goals, or acquiring badges, users can advance the plot or story, and if they are invested in the characters or storytelling, this may provide additional incentive during the gameplay. The story can either be spaced out and given to the student in chunks as they meet these goals or interspersed throughout the gameplay, in which the student's in-game actions have a direct influence on the plot or characters.
- Feedback: It is important for students to know how well they are doing within the game, and feedback is the communication between the game and the user. Important variables are frequency, intensity, and immediacy of this feedback, where more frequent and immediate feedback allows more effective learning and engagement. User immersion is also related to the quality of feedback.

A number of classroom gamification user studies have been published. Paul Denny looked at badges for multiple choice responses in class to motivate participation [9]. He found increases in the number of responses, but students did not say they learned more and the quality of responses did not improve. However, engagement levels varied between students in the class. Dominguez et al. designed a gamification system for Blackboard, a virtual learning environment and classroom management system [10]. The system featured a leaderboard, trophies, and achievements. Only 44% of the experimental group participated, possibly due to some students' expressed dislike for competitive elements in the system according to the authors. While overall scores and scores on practical assignments were higher for those who participated, scores on written material and participation were lower.

According to a meta-synthesis of gamification studies from a variety of sources, gamification has had a positive outcome most of the time, although only a couple times did studies find positive outcomes for every test. In a number of these studies, while positive results were reported by students, the papers did not provide any inference or analysis. Several of these studies also make the claim that the results of gamification may not be lasting due to a novelty effect. As students grow tired of a game, the motivating factor may decrease. Another aspect to consider when implementing gamification is that removing gamification from the setting may be detrimental to users due to losing progress they had made. This negative feeling may contribute to decreased motivation after gamification is removed.

Barata et al. [30] gamified a college course using points, levels, leaderboards, challenges, and badges. Their results show increased student engagement and participation in class activities, especially for those online and outside of class. Additionally, students were more motivated to attend lecture, and this was shown via an increase in lecture attendance. On the other hand, student grades did not improve meaningfully.

Berkling and Thomas [31] utilized web-based gamification to teach a college course, including elements such as achievements, points, levels, and leaderboards. The gamification platform also provided the instruction. Survey responses indicated students weren't interested in this environment because they didn't find it helpful. The authors found that those with more experience with traditional teaching styles were less enticed by the gamified approach.

Brewer et al. [32] researched gamification on children by introducing a scoring and prize system, attempting to increase a task completion rate. Results showed an increase in task completion rate from 73% to 97%, indicating that gamification helped motivate the children to complete the tasks.

Classroom Live [20] was developed for a college computer science classroom, and included gamification elements such as points, levels, and rewards. Survey results showed students found the class more enjoyable than other classes and were more engaged during class than in other classes.

Eleftheria et al. [33] have proposed the use of an augmented reality book using gamification for science education. Student motivation was targeted through the use of points, levels, badges, challenges, and unlockable content. By incorporating these elements, the authors hoped to make the learning more engaging, enjoyable, and productive.

Gibson et al. [34] describe badges combined with points and leaderboards as a way to create competitions and create a system in which students can attain their goals. This can improve performance, as users can show better engagement, skill acquisition, and time management.

WebWork [35] was designed using points and achievements to help motivate students to do their homework. Results indicated that students with high homework scores also had high scores on WebWork. This also increased self-reported feelings of accomplishment.

Kapp [36] discusses the increase that can be seen when students are engaged in the learning process through gamification. More rarely discussed gamification elements such as storytelling and feedback are discussed along with the balance between learning and gameplay, which is an important element for a successful gamified education setting.

Kumar and Khurana [37] found evidence that students are not as interested in learning programming languages in traditional classrooms using traditional methods. By using gamification elements such as levels, points, and badges, student interest increased and motivation was fostered. They state that "learning with fun" is the goal of educational gamification, and without this, the goal is not met.

O'Donovan et al. [38] implemented gamification elements such as story, points, progress bars, badges, and leaderboards into a game development course. A survey was administered to students, and results showed an increase in student engagement/attendance and performance/grades.

Raymer [39] posits that frequent feedback, progress, character upgrades, effort-based rewards, and peer-to-peer interaction are all sources of motivation which can help increase student engagement.

Santos et al. [40] used badges in a classroom setting to see if user experience improved. Over 90% of the students indicated that the badges helped them focus, stay motivated, and stay engaged with the learning setting. Students agreed that the badges led to a feeling of achievement during class.

Todor and Pitic [41] introduced gamification elements such as an avatar, points, badges, and rewards in an online class. Results show increased student interest in class compared to a traditional classroom setting.

Villagrasa and Duran [42] utilized a storyline and scoreboard in a 3D art class to gamify the course content with the goal of increasing student motivation and engagement over traditional learning approaches.

Stott and Neustaedter [55] analyze two case studies, noting the legitimacy of gamification in practice. The first was Dr. Lampe's 200-student study [59], in which he identified choice, rapid feedback, collaborative processes, and competition as effective elements of gaming in his class. The second, and closest design to that of TINGLE, involves Just Press Play [60], a game developed not for classroom learning, but as a gaming layer to incentivize students to perform activities healthy for their academic development, such as making personal connections with faculty, attending workshops, etc.

2.3 PLAYER TYPOLOGY

Player typology and player traits, the idea that different people like different games and mechanics, have been studied for many years [15]. By understanding why people like certain games, we can better determine in advance which games people will like. This is important because students who don't like games or who don't have a long history of playing games may not be able to identify which games would be motivating to themselves. In TINGLE, the long-term goal is to use player typology and player traits to identify which games are most likely to be motivating to a particular student. Early research into player typology [15,16] explored psychological types as a way to explain player preferences. However, recent developments have led researchers in the direction of trait theory, or a person's game preferences can be quantified on one or more trait scales, rather than type theory, which attempts to categorize a person into one type.

One popular method of dividing players into types has been using different methodologies to classify gamers as either hardcore or casual. This can either be done as the entire basis for player categorization or as part of a more comprehensive method. According to Ip and Jacobs [43], hardcore players are more dedicated to the different elements of gaming, displaying deeper knowledge of the game industry, engaging in longer and more frequent gaming sessions, and interacting more with online forums related to gaming. They want to be considered beyond mainstream and have desire or ambition to modify the game experience to suit their tastes. As a sole method of player typology, this method has been criticized [18] as too simplistic. To address this, Stewart [44] claims that a hardcore gamer is immersed in the game world to a certain extent and that the hardcore/casual dimension is continuous, rather than discrete. Furthermore, hardcore players want to be intellectually stimulated by their gameplay, which provides interesting adventurous experiences. Because of the vast differences in definitions of hardcore and casual among various literature and disagreement about how it should be measured, it is apparent further research is necessary to better understand player preferences. By simplifying players into just these two types, especially based on suggested game genres that appeal to one type or the other, this literature is ignoring those who may identify between the two extremes.

The most popular method of determining player type is to look at how players behave within the game. This behavioral analysis is based heavily in psychological literature. For instance, Drachen et al. [45] classified player experience in Tomb Raider: Underworld into four different playstyles: veterans, solvers, pacifists, and runners. Each of these were methods for solving problems and interacting with the world that each led to the completion of the game, but may have had different numbers of deaths and completion time, both of which were logged. Veterans were the most experienced players, dying rarely and completing the game quickly. Solvers would take their time while playing, making sure to solve any optional puzzles along the way. Pacifists died because of encounters with enemies rather than from environmental hazards, such as falling. Runners were less experienced gamers who still tried to complete the game as fast as possible.

Richard Bartle initially attempted to explain player typology by placing a person along two continuous bipolar axes, one being explorer vs. achiever and the other socializer vs. killer [15]. This was done in Multi-User Dungeon designs. The axes can be thought of as acting vs. interacting and players vs. world. An achiever acts on the world. An explorer interacts with the world. A killer acts on players. A socializer interacts with players. Criticism of this model focuses on oversimplifying the player model. Additionally, the model fails to account for the fact that player preferences can change based on the game genre or atmosphere within the game. An achiever in an incremental game may be more of an explorer in an exploration-based game. Without proof these types don't overlap and are not mutually exclusive, the model has not aged particularly well.

Yee [46-48] published his Achievement and Social factors using Bartle's player types, and the results were similar, but not perfectly analogous. While there were initially five factors, later work increased this to three main factors (Achievement, Social Interaction, and Immersion) and ten sub-factors. While Bartle didn't look at immersion, Yee showed it was a major motivation for play.

Stewart [44] combined Bartle's player types with Keirsey Temperaments [49], concluding that all player behavior can be explained by currently existing behavioral research, such as the Keirsey Temperaments. These temperaments are Artisan, Guardian, Idealist, and Rational. This was shown by connecting unrelated research to game studies. While this model explains games very well, it was not paired with a user study to verify its predictive power to game preferences.

Zackariasson et al. [50] used Yee's work to analyze buying behavior in massively multiplayer online games (MMOGs). By combining Yee's motivational factors with identity construction, they attempted to model online player personas. The final types were labeled progress and provocation, power and domination, helping and support, friends and collaboration, exploration and fantasy, and story and escapism. These were justified by tying them to one of Yee's three major motivational factors.

Tseng [51] used the need for exploration and the need for conquering to explain game motivations. In this model, exploration also entails social and achievement desires. The need for conquering was heavily based on Bartle's Killer type, enjoying defeating others and seeing their misery. Using these segments, Tseng used factor analysis to break gamers down into aggressive, those who score highly on both segments; social, those who score highly on exploration but low on conquering; and inactive, those who score lowest on exploration, but moderate on conquering.

Studying how people act and interact within Lineage, an online game, Leo et al. [52] classify players into single-oriented, community-oriented, and off-real world. If one falls into single-oriented, they treat a game like a single-player game, preferring to act alone, even if the game has interactive elements or focus. Community-oriented players prefer to interact within the community and are social in nature. The off-real world player prefers to use any means necessary to achieve personal goals and may be anti-social. They also may be aggressive or discriminative, which the single-oriented player is not.

Kallio et al. [53] discarded prior type theory in favor of a new model looking at the reasons people play games in the first place. They ended up with three major motivation categories, including social, consisting of playing with children, playing with significant others, and playing with company; casual, consisting of filling spare time and relaxing; and committed, consisting of playing for fun or entertainment and playing for immersion. This kind of typology is genre-independent. Because the reasons we play games are so complex and the way we play are dependent on many factors independent of the game mechanics, they argue that placing gamers in strict types based on game mechanics is ineffective.

Nicholson [54] discusses the merits and drawbacks of reward distribution. He argues that rewards are ineffective for long-term behavior change and that a more complex gamification model is necessary to keep long-term engagement and interest. As Deci and Ryan [58] show, extrinsic rewards replace intrinsic motivation, and therefore when rewards stop, often the associated rewarded behavior also stops. This can be seen in public education where students have less motivation to engage in ungraded tasks or with pedagogical content when told it will not be on a test. Nicholson [54] argues that the successful way to foster long-term engagement is through building intrinsic motivation. By designing systems that help users discover their own reasons for engaging with a behavior, also known as Self-Determination Theory, users can build mastery, autonomy, and relatedness, all of which have been shown to boost self-motivation. By designing gamification around these principles, Nicholson argues that the outcome will be as successful as reward-based gamification, but there will not be as many long-term issues. The 6 elements he presents for successful long-term gamification include:

- Play, which is the freedom to explore and fail without boundaries.
- Exposition, or creating, or allowing users to create, integrated real-world stories.
- Choice, giving the power to the users.
- Information, or using game design elements to allow participants to learn about real-world contexts.
- Engagement, which is encouraging the participants to discover and learn from other participants who are also interested in the real-world context.

- Reflection, assisting participants in finding interests and past experiences that can deepen engagement and learning.

Researchers followed up on Bartle's model by attempting to use a player's Myers-Briggs Type Indicator [63] results in order to predict player type. This was first explored in the first Demographic Game Design model (DGD1) in 2005 [16]. MBTI results were used to classify players as conqueror, manager, wanderer, or participant. In addition, it was found that the common perception of hardcore vs. casual players was not a method of play, but rather was found in all four types, not as a play preference, but as a trait dimension. This finding led to an alternate approach, DGD2, which used Temperament Theory [17] to create player archetypes such as Logistical, Strategic, and Diplomatic as well as link to MBTI results since Temperament Theory and the MBTI have similar theoretical foundations. DGD2 focused on playing preferences, emotional responses to game situations, and a player's game skills [10]. Results from a 1040-player survey indicated that 40% of players prefer to play solo, 17% prefer same-room multiplayer, 19% prefer to play over the internet, and 16% prefer to play massively multiplayer online (MMO) games. In addition, 93% of gamers felt that a story is very important to the enjoyment of a game. 35% feel compelled to acquire everything possible or repeatedly pursue actions because they can make large gains, yet only 9% actively seek out games for this reason.

Subsequent to the development of DGD2, a model called BrainHex was developed using neurobiological factors to create player archetypes [18,19]. Seven defining traits were determined, but a player receives a score in each of these seven traits rather than a single type, as many prior studies had done. Each of the traits represents a motivation a player may have to play a game. The types vary from Seeker, one who enjoys exploring the game world and looking at scenery, to Mastermind, one who enjoys solving puzzles, to Conqueror, one who enjoys beating difficult bosses and player-versus-player combat, to Achiever, one who enjoys striving toward self- or game-defined achievements, such as collecting items or reaching a certain power level. While the researchers behind BrainHex admit this method has had flaws with its factor analysis, it seems to me to be the best player typology for this line of research moving forward because it does not assume a game is being played within a course context, nor does it assume games are trying to teach course content. Many other competing player typologies are created to optimize the development of learning games and are not appropriate for topic-independent classroom gamification.

Since BrainHex, there have been more attempts to model player typology, but no major advancements have been made.

2.4 LIMITATIONS OF EXISTING LITERATURE

Literature involving classroom gamification, including the studies and commercial applications explored above, has often involved a game deployed in the classroom itself with the goal of helping teach students the learning content. However, with this "one game for many students" approach, the authors are assuming all students want to play this game or are motivated by it. Any change in motivation to engage with the deployed game creates an unfair advantage for some students, especially for those who like games, but may not be motivated by the mechanics or interactions within the particular game. For instance, one student may like cooperating with friends or strangers, while another may like competing with friends or strangers. Some other student may just want to play by him/herself. One student may like

RPGs, while another likes real-time strategic decisions, another likes shooters, and yet another wants to feel the rush of high speed action. It is very difficult to engage each of these students. In some cases, by prioritizing one style of interaction over another, one can alienate some students. If you force a competitive student to cooperate with someone who likes cooperation, you may get an experience where the competitive student tries to sabotage the cooperation in order to prioritize his/her own preferences, ruining the experience for the student who likes cooperation. Another consideration when using gamification in class itself is that some students do not like games at all. By turning the classroom atmosphere into a game, some students may be or feel forced to interact within a setting they are uncomfortable with. In such a setting, these students may desire to opt out of the game setting. Unfortunately, with a game embedded in the class, students who want to opt out of the game end up having to opt out of learning unless the instructor is willing to work with them individually to teach them the same learning content the game is supposed to teach.

When learning content is embedded in a game, it creates the need to develop game content for all of the learning content, which is expensive both from a development and monetary perspective. As an example, if an embedded game is attempting to teach students multiplication, certain game mechanics will work better than others to achieve this. When these students move on to fractions, the same content likely will no longer be optimal for teaching this new content, creating the need for the game developers to develop new game content. This issue is even more apparent when students switch subjects or courses. The mechanics needed to teach math are very different from the mechanics needed to teach history or English. The other issue this presents is that the developers of the game or someone overseeing the game’s development must be familiar with pedagogical approaches for this course content. Without an expert designing the embedded learning content, the game may not be teaching students as well as it could be and may not be accessible. This is another potential expense during development. For this product to be profitable, the cost of the product will need to make up for all development costs. This can drive up the price of the final product, possibly pricing it out of the range of low income schools.

Deploying gamification in class often requires the instructor to have a certain level of technical expertise. A game is only as fun as the experience. If there is a long setup time or breaks due to technical difficulties that are not fixed in a timely manner, students may lose interest in the game, and it can cause the instructor to become overwhelmed. In addition, with an embedded game, the instructor does not have full freedom over how the learning material is presented. They may be experts at presenting certain curriculum, but if a foreign game teaches students for them, they are left trying to complement the game's teaching style rather than having the full freedom to create a learning atmosphere, which is their specialty to begin with. Gamification should not feel like an intrusion to anyone.

For many years, gamification was synonymous with points, badges, leaderboards, and achievements. By incorporating these mechanics into the classroom, you were gamifying it. However, gamification and game preferences are more complicated than this. Leaderboards are inherently competitive in nature, and more motivating if you are near the top of the leaderboard than if you are near the bottom. These concepts are more motivating if you are already doing well than if you are not. Having another mechanism in class reminding you that you are behind others may not be motivating to students who most need the additional motivation.

Finally, in the case of gamifying your life, giving a user power over their own gamification is unlikely to create a long-term habit. With an app that is unable to actually verify if you have done the intended behavior, the user can reward him/herself for an action he/she may not have done. It is important for gamification techniques to be able to track user behavior in such a way that they are not in control of their own reward. This way, the reward means more because it can only be acquired from an outside source.

2.5 CONCLUSION

The main focus of classroom gamification research to date has been on games deployed in the classroom for motivational purposes. The results of these studies are almost all positive, with classroom gamification showing increased motivation and engagement in class. However, while the overall results may be positive, the design may be detrimental to students with certain learning or gaming preferences. Classroom gamification design should be beneficial to as many students as possible and minimize the number of students for which a detrimental effect exists. This hole in prior research is what I aim to address with TINGLE's methodology and approach. This dissertation's major points of departure from existing research include:

- A disciplinary- and content-independent gamification framework such that instructors do not need to change their existing course materials or pedagogy and do not need technical expertise to gamify their class.
- Identification of the factors that are most positively affected by game engagement to help us understand how games and instruction could be differentiated for individual students.
- Identification of socioemotional factors such as motivation, interest, and efficacy in the game tied to classroom engagement via the gaming elements.

CHAPTER 3: TINGLE METHODOLOGY

3.1 INTRODUCTION

This chapter will serve as an introduction to TINGLE's methodology development, vision, and validation. The motivation for this chapter comes heavily from the arguments made in Section 2.4. By addressing the limitations in prior research, TINGLE aims to offer a gamification environment that is more accessible to students and instructors while being easier to develop by non-experts in pedagogy.

3.2 TINGLE DEVELOPMENT

The defining aspects of TINGLE can be best described by describing a typical gamification environment and arguing for each change that is made from that environment. We start with a single game deployed in a classroom setting with the goal of teaching students educational content by augmenting game mechanics with pedagogy.

The first change to this typical gamification environment is to individualize the game to the student. This gives each student a game they actually want to play. By doing this, we address the issues of students playing a game they do not like, or engaging in mechanics they do not enjoy. Cooperators want to play games together so they will get matched together. Similarly, competitive students will get matched to engage in competitive tasks. Students who would rather play a game by themselves will get that opportunity with mechanics that motivate them. Students are now on more equal ground within the gamification aspect of class because we are addressing the inequality of prior gamification research, in that some students may be more motivated than others to play a particular game, especially if it aligns with their learning or gaming preferences.

Next, we will remove the game from the classroom setting, and instead the game will be played at home. This allows increased development flexibility since the instructor no longer needs to spend class time fiddling with technology and can focus on what they are specialized in: teaching. Rather than teaching to a game, instructors have the freedom to present content the way they want and have experience and success with. This also removes the limitation of only deploying a single game or mechanism due to the instructor's inability to create complete and equal pedagogical content for many games at once. In class, each student needs to be focused on the same environment. At home, however, students are in a familiar and individual setting, which is easier to customize to each student's preferences.

By removing academic content from the game, we make a number of positive changes to the game's motivational potential. For a student struggling in class, even playing a fun embedded game may not help the student if they want to escape the feeling of frustration and failure. By minimizing the differences between the game deployed as motivation and a game the student would play outside of class for fun, we maximize the motivational potential of the game. There are a number of cases each year of students ignoring their own basic needs in order to continue engaging with a game. While we want to avoid gamification becoming or leading to an addiction, using the power of addicting game mechanics in a limited setting is a powerful extrinsic motivator when convincing someone to prioritize a task they are not intrinsically motivated to engage with. In addition, by making this change, the game is now topic- and content-independent. There is nothing that ties the game itself to individual pedagogy or learning content. The game can now be used across disciplines.

At this point, there is no difference between this approach and any other game designed to just be fun. To reintroduce ties back to the classroom, we link progress in the game to measures of curricular effort. This creates a self-reinforcing cycle where a student, finishing a game session of a game they are intrinsically motivated by, will desire to continue to make progress in the game. By gating further progress in the game behind curricular effort, the student is incentivized to refocus this motivation to progress further in the game into their coursework. By continuing to show effort in their curricular learning, they can gain additional game progress. If access to the game is limited such that students reach the end of a play session before they naturally want to quit, that desire is stronger [73]. Thus we limit access to the game. Another reason this is necessary is it is possible students play the game at the expense of their coursework, which goes against the purpose of this intervention. By allowing students unlimited access to the game, we allow potential addiction and priorities that are not in line with maximizing student motivation and engagement in class and on coursework.

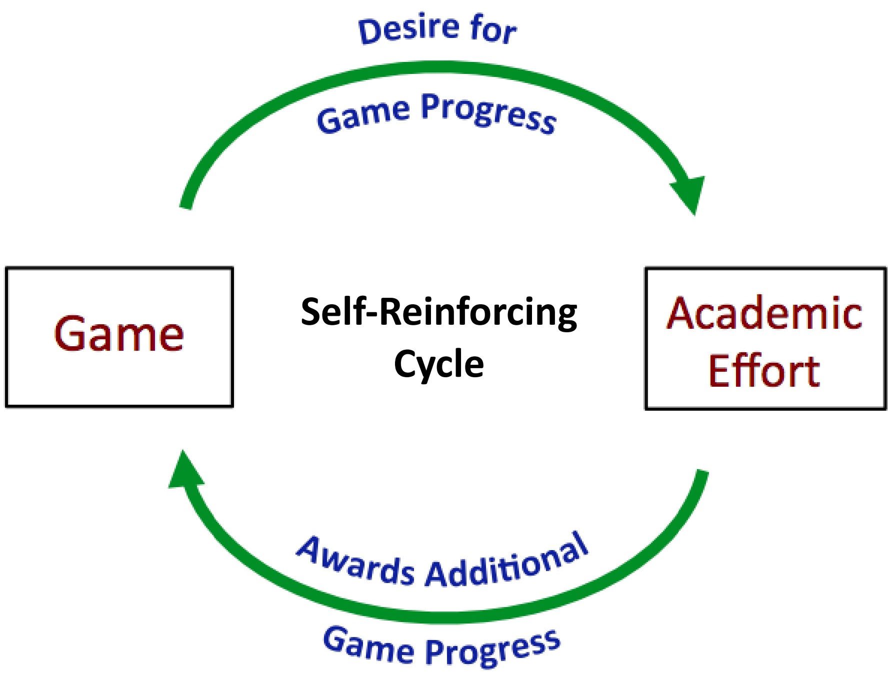

Figure 1: TINGLE Self-Reinforcing Cycle

This methodology leads to my research hypothesis: A student playing a content-independent game, outside of class, but with ties back to curricular effort, will experience increases in self-reported motivation and engagement in class as well as an increase in grades.

3.3 TINGLE VISION

My vision for TINGLE involves a number of priorities that are important to keep in mind during planning and development. The first is the need for accessibility, especially among students. I want TINGLE in every school and learning opportunity that will accept it, and I want it to be as successful as possible for as many students as possible. This means keeping in mind every student's experience and developing content that is accessible to women as well as men, international students, and students who say they do not like games. It is a priority to ensure I am not providing an unfair advantage for any particular group of students and that every student has an equal opportunity to use this tool to succeed. While this diversity testing has yet to be implemented, it is an important consideration for future work and the continuing development of TINGLE.

By using an online platform and digital distribution, there is no cost forr deployment, and the only cost is initial development and maintenance. This will allow TINGLE to be profitable even with a low cost. It is important to me to keep TINGLE affordable, especially to low-income schools. This feeds back into my priority of accessibility, as I do not want to exclude low-income students from benefiting from TINGLE.

The development of TINGLE is inherently cross-platform, allowing students with personal computers with different operating systems, tablets, or phones to be able to access the games that make up TINGLE. This is accomplished by using the flexibility of the Unity development engine's publishing tools.

TINGLE is developed to be cross-pedagogical. I envision a system where students can go from class to class or subject to subject and make progress in the same game outside of class by providing differently measured effort in each of those classes or subjects. There exist many ways to measure effort, and by creating formulas for converting effort in and out of class into a number, we can use that to award progress in the game. Prioritizing a cross-pedagogical approach minimizes the disruption on existing curricula. This does not require instructors to change their teaching style to accommodate TINGLE, making it theoretically a fit in any classroom atmosphere where it is possible to assess effort.

Because educators will have different ideas about the extent to which they want to integrate TINGLE into their class, it is a priority to minimize the difficulty of that integration. I strive to build a model that can exist and motivate students without any instructor effort at all. That said, for instructors who want to be more involved in the measurement and reward of progress in the game, I have tools to allow them to be more involved. Instructors can find their own ways to measure classroom effort, some of which may be difficult or impossible to automate with current technology, and using an easy script, they can customize how, when, and to what extent their students are rewarded. The goal here is that TINGLE will work with or without instructor involvement, maximizing the accessibility of this approach.

Finally, I prioritize ease of data access. Instructors should have access to the effort data TINGLE collects, as this could be used to better understand students and help the instructor craft their own lessons based on where and how their students are struggling. Of course, just because an instructor has access to this data does not mean they need to use it. Instructors should be free to manage their classroom in a way that utilizes their individual strengths.

3.4 TINGLE VALIDATION

To validate TINGLE's approach, this section will present arguments about the worst-case effect of TINGLE, the reasoning behind using effort-based measures rather than performance-based measures to reward game progress, and some of the potential benefits of using TINGLE in terms of character development.

I first validate TINGLE by comparing the worst-case effects of traditional gamification approaches with TINGLE's approach. In traditional gamification, a game is played in the classroom in order to learn course content. In the worst case, a student does not wish to participate in the game and wishes to opt out. In this case, a student participating in traditional gamification opts out of learning in addition to playing the game because the learning is embedded in the game. It is then up to the instructor to create individual lessons and give individual attention to this student. This often means that participation in the gamification is mandatory. A student opting out of TINGLE no longer benefits from the motivational effects of playing a game outside of class, but still has every opportunity presented by today's classroom environment. In the worst case, TINGLE is still able to offer every opportunity available in classrooms today, and without mention of the games in class, the in-class experience for students participating in TINGLE and those opting out are as close to identical as possible.

I defend measuring student effort as the method for rewarding game progress by comparing it to the alternative of using performance-based evaluation. Not every student is capable of perfect performance on every learning activity at all times. By giving a student feedback on their performance relative to perfection, we may be failing to recognize and incentivize improvement. The way to maximize a student's performance relative to their current performance potential is for them to apply maximum effort over an extended time. By creating arbitrary performance threshold requirements, we may be inadvertently dissuading some students from trying their hardest. As an example, a student who is currently capable of a "D" grade with maximum effort may receive negative feedback regardless of the amount of effort they put into their work. This may cause them to wonder what the point of trying at all is if they are going to fall short of expectations. But in the long term, the way to maximize the chance they succeed is for them to apply maximum effort now. This may result in a "D" grade now, but the material they learn from this can be used moving forward, potentially improving future grades. We want to motivate this student to put maximum effort into their work regardless of the outcome. How do we do this? My idea for this is to compare the student's performance now relative to the student's performance in the past. By applying effort to their learning, a student is theoretically capable of continuous improvement as anything learned in the present unlocks more potential understandable knowledge in the future. By rewarding students for knowledge acquisition, they are theoretically capable of positive feedback at every check-in point, which is more motivating than negative feedback. Similarly, a student capable of consistent "A" grades may not be motivated to apply 100% effort in a class if they can apply 80% effort and still get an "A." However, by not engaging in the class to the best of their ability, they may not be learning as much as they could have, and their ability to recall learned information years later may be compromised. Additionally, future content may be more difficult to learn. If applying less than maximal effort becomes a learned behavior, it may be more difficult for these students to succeed when the difficulty of pedagogical content increases, as they may not have the skills or motivation necessary to put in the effort required to succeed. Such students need additional motivation to apply more effort than is necessary to reach the "A" threshold. TINGLE's effort-based approach rewards students who may struggle to get good grades but still try their best, and fail to reward students who do well but may not be applying full effort.

TINGLE also develops skills that will be beneficial to students throughout the rest of their lives. By separating the learning from the reward, students are able to build skills for pushing through difficult tasks. When the reward is no longer present, even if students are no longer striving for the reward, if they are motivated to get the work done, they have experience working hard and know what they need to do to get the work done. On the other hand, students without that experience may not know how to proceed in settings such as this. In addition, since these skills are built independently, they are capable of succeeding independently.

Finally, since TINGLE delays the reward until after class, students learn the important life skill of work in the absence of immediate reward. Life is full of scenarios where this is the case. Work now, get paid later. Work out, be fit later. Having experience applying effort despite the lack of immediate reward allows people to think about and prioritize the future over the present, which helps guide the development of decision making.

3.5 CONCLUSION

This chapter introduced the motivation and methodologies behind TINGLE and provided theory and arguments for why it may work. By individualizing the game to the student, removing the game from the classroom setting, and removing academic content from the game, we maximize the motivational potential of the game. By tying the game back to curricular effort, we incentivize students to try their hardest on class material in order to continue making progress in their game. This system has numerous benefits for the development of a strong work ethic regardless of the result of that effort. Further research and analysis is needed to prove these statements, but the foundation for successful content-independent gamification is here.

CHAPTER 4: PILOT STUDY

4.1 INTRODUCTION

The goal of this initial pilot study was to determine a baseline for the effects of having students play a game outside of class, but without tying progress in the game to effort-based measures in class. The results of this study will be used to determine if there is a significant difference between students playing a game outside of class and students playing a game outside of class with ties back to class. We hypothesized that the game would have no significant effect on students' self-reported motivation or engagement in class or on their grades. We successfully showed that without ties back to class, the motivational effects of the game deployed were not significant. Moving forward, we can use this as a baseline for comparing the results of games deployed in classrooms with ties back to class.

4.2 TECHNOLOGIES USED

For this pilot study, the game was coded using Javascript and Limejs. Javascript is commonly used for simple online games due to an extensive library and easy-to-use online tools. Limejs is an open source platform for easily creating 2D games. These were chosen for their ease-of-use as the goal was to have a fully functional game in one summer. The game for this pilot study did not need to have flashy graphics in order to test the baseline effectiveness of deploying a game in a classroom setting so I opted to prioritize development speed over graphics. In addition, Javascript and Limejs run on every major browser (and thus operating system) increasing accessibility among students in the deployed classroom. The game was designed such that the mechanics could be learned in a very short time, allowing players to maximize the time spent playing and enjoying the game and to minimize risks of frustration and quitting. The mechanics of the game were also designed to only appeal to a subset of player traits, maximizing the measurability of the effects of the game on classroom engagement. Furthermore, Limejs makes it easy to enable mobile support. This was important to prioritize in order to minimize barriers to game access and to maximize the number of students playing the game in the short- and long-term.

4.3 GAMEPLAY

The pilot study game is a Role Playing Game (RPG), a genre in which players take the role of imaginary characters that engage in adventures, typically in a fantasy setting. The basis of the game is that a player-controlled hero is allowed five adventures per day to fight monsters. The hero starts out weak, but can use upgrade points acquired from defeating monsters to increase the rate of item drops, the number of monsters that can appear in fights, and the difficulty of those monsters. Item drops from monsters can be used to upgrade the hero's attack, attack rating, defense, and defense rating, making the hero more resilient and better able to survive encounters with more and stronger monsters. This design only rewards actively playing the game and does not reward doing well in class. This was done to set a baseline to improve upon for future iterations of TINGLE with ties back to the class, and to quantify any motivation tied to the novelty of having a game to play for class. One concern with a design where the student needs to interact with the game to succeed in the game is potential addiction. We handle this by limiting the student to five monster encounters per day, which requires only a few minutes per day of active gameplay. This ensures students are not prioritizing the game over their learning, and hopefully, in future iterations, once the student can no longer play the game actively, they redirect the desire for progress to an activity that indirectly helps them progress in the game, which can be any number of course activities such as doing homework, studying for an exam, or attending class.

4.4 METHODS

In order to validate TINGLE, the game was deployed in a 131-student construction graphics class with 131 construction management and civil engineering students during the Fall 2015 semester at Washington State University. While the goal of TINGLE is to eventually tie progress in the game to progress in the classroom, the pilot game did not affect the classroom. This was done to set a baseline for future iterations, in order to account for potential biases due to factors such as the novelty of a game played for class.

Data collection for the game involved tracking the login timestamps, login durations, and number of clicks recorded because they correlate with the student's engagement. Weekly Likert-scale surveys were also administered via Blackboard, asking the students what benefits they noticed from playing the game in terms of engagement, grades, motivation, and fun. In addition, an end-of-semester survey was administered, including more detailed and open-ended questions about prior experience with games as well as their experience with the game in the class.

To record preliminary data regarding the interaction of game type and personality preferences, the Myers-Briggs Type Indicator (MBTI), a personality profile with extensive research history, was offered online free of charge to all students in the class during the first few weeks of the semester, which was before the students began playing the game. 91 students chose to complete the MBTI. The MBTI was selected due to its easy public availability on campus as well as the potential to find significance among any of the four bipolar axes and with each of the 16 MBTI types. This allows for both type- and trait-based analysis. The results of the MBTI were made available to the students. While there were a few weeks between students taking the MBTI and playing the game/filling out surveys, it is assumed that their personality metrics were stationary over that time.

4.5 RESULTS AND DISCUSSION

Unfortunately, due to low student participation in the weekly surveys, extra credit needed to be offered for a significant sample of students to fill them out, creating a potential conflict of interest for students filling out these surveys. Surveys were crosschecked with logins in order to ensure the student had played the game that week. As such, we cannot make any causal claims about student motivation leading to increased logins, login durations, or number of clicks within the game.

For the weekly surveys, submissions were rejected without the appropriate answer to a weed-out question as well as if a student had not played the game that week. This left 58 total survey responses which were used for the following analysis.

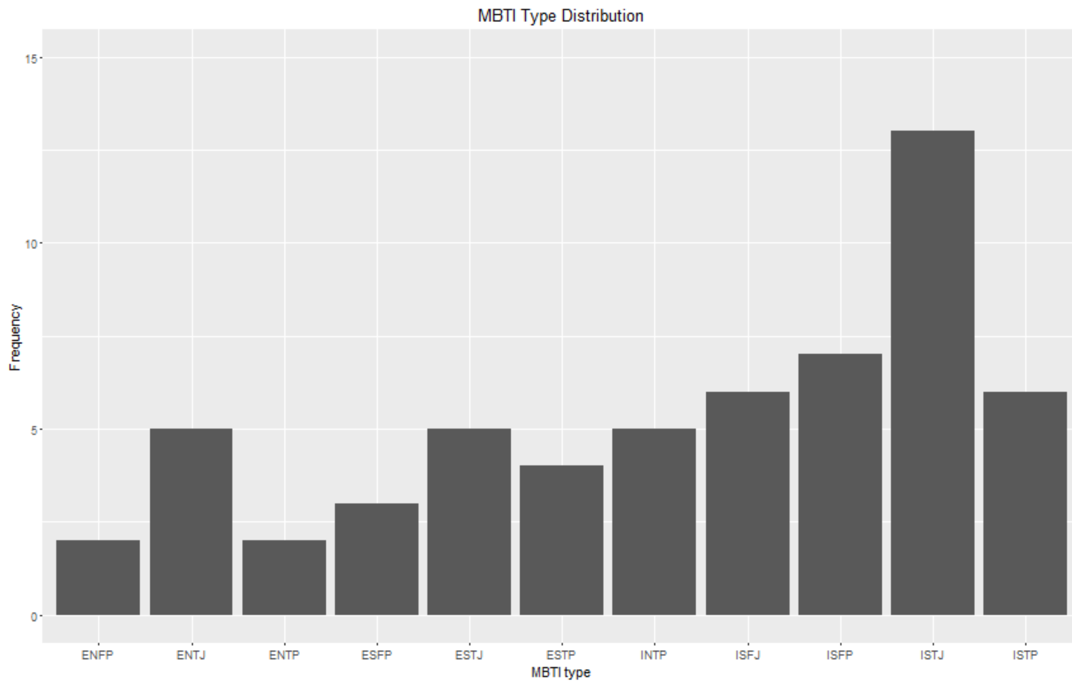

Figure 2: Frequency of each MBTI type in survey responses

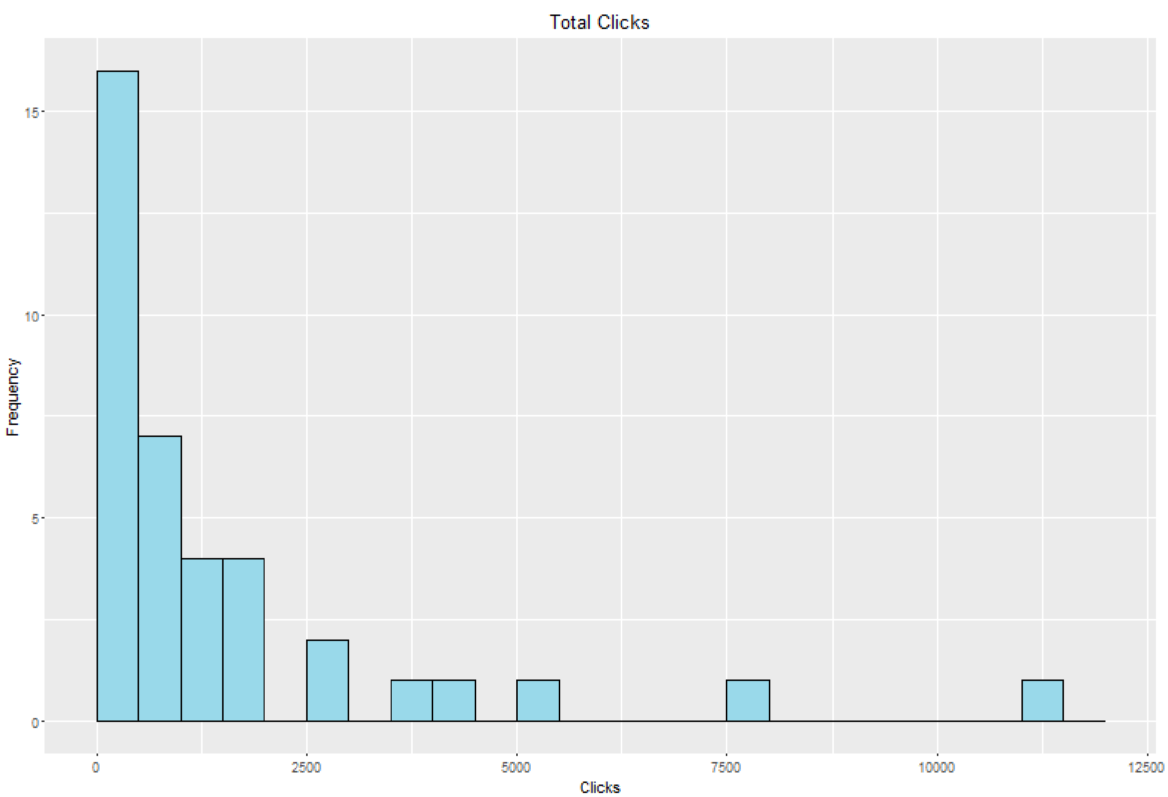

Figure 3: Number of in-game clicks registered by each account over the whole pilot study

Figure 2 shows the distribution of MBTI types among survey responses. There was representation from 11 of the 16 types, with most respondants classified as introversion over extroversion, sensing over intuition, and thinking over feeling. There were an identical number of participants classified as judging and as perceiving. Considering the sample was from construction management and civil engineering, this skew makes sense, as the strengths of the field align with the strengths of the traits heavily present in the sample. To determine how much each participant played the game, the number of clicks, or taps on a mobile device, were recorded and aggregated over all play sessions. Figure 3 shows the distribution and frequency of clicks over accounts. Clicks were registered whenever the left mouse button was pressed somewhere in the active game window. While it is possible a click could be registered without changing the game state, it is assumed that all clicks were intentional and showed the desire to interact with the game. Clicks were used over login durations because with no timed logout, participants could be logged in while not being active in the game, or even while not at their computer. A click shows at least a basic level of interaction with the game. Most participants did not experience much of the game — this may have influenced their responses. Without ties back to class, there was minimal external reward, and these results provide evidence that the game by itself was not motivating enough for participants to continue playing.

Survey results were collected using a 7-point Likert scale, where the responses allowed were:

- 1 - strongly disagree
- 2 - disagree
- 3 - slightly disagree
- 4 - neither agree nor disagree

- 5 - slightly agree
- 6 – agree
- 7 - strongly agree

Question	Mean Survey Response	Standard Deviation of Survey Responses
The game helped me engage with classroom material	2.98	1.48
I identify with the protagonist	3.98	1.73
The game improved my grade	3.91	1.67
The game helped me learn	3.26	1.57
The game was engaging	3.66	1.66
The game was fun	3.74	1.72

Table 1: Pilot study survey responses

Survey results show that the participants felt the game was least useful for helping them engage with classroom material. With no ties back to class, this result makes sense. Participants answered more favorably to questions about the extent to which they identified with their game character and the effect it had on their grade. Since slight extra credit was needed to

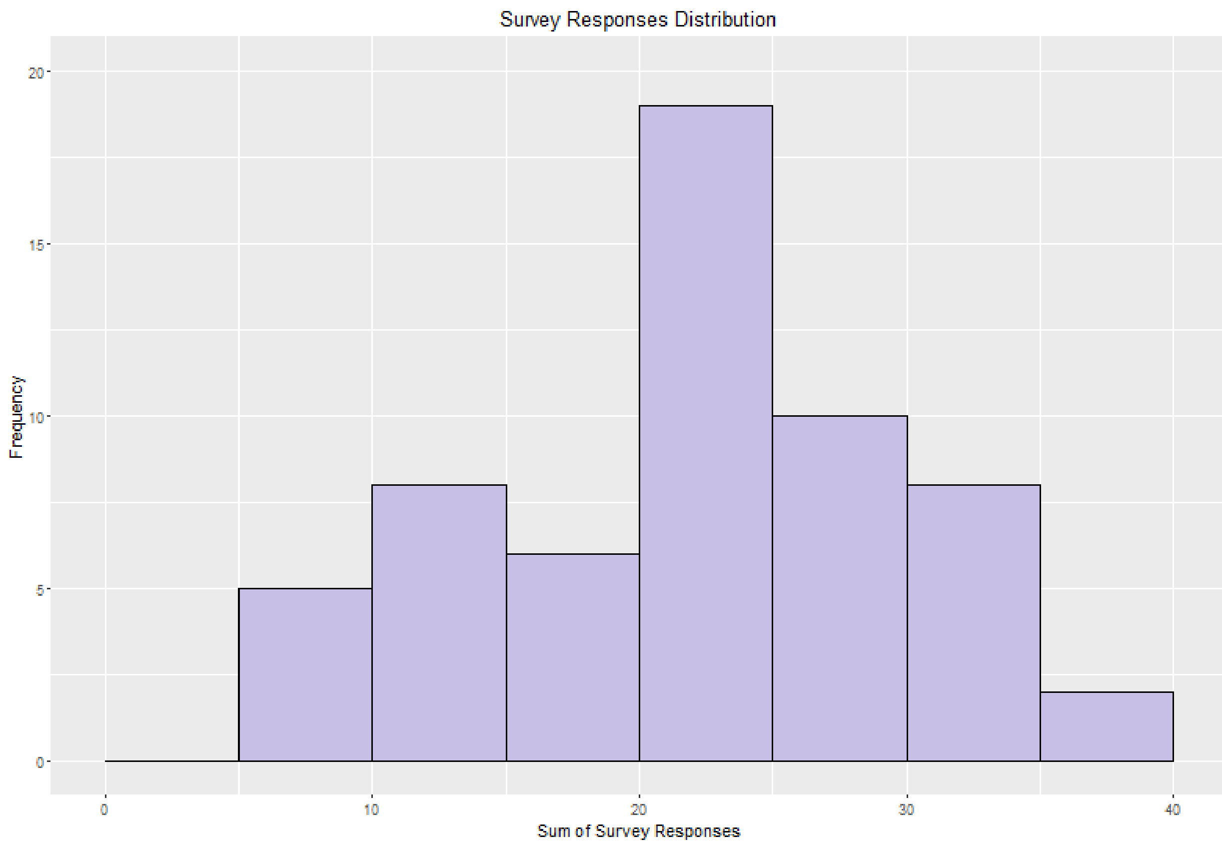

Figure 4: The sum of each student's survey responses

convince participants to fill out surveys, it is likely that is responsible for that question having a more positive response rather than the game itself. However, a couple students played a great deal of the game. Both of these participants were ENTJ and their surveys contained neutral or positive responses for most questions. The game had a number of repetitive tasks, and the last two questions were designed to collect data on whether or not there was disparity between what was intended to be an engaging task that only a subset of people might find fun. With survey response deviations this narrow, no such conclusion can be drawn. Finally, to determine the extent to which participants in general liked or disliked the game, the standard deviation of the sum of their responses was taken. At 8.06, this value shows there was spread among participant's overall opinion of the game. Figure 4 shows this distribution. The spread reinforces the idea that no game is right for everyone, and while some participants enjoyed it, some did not.

To determine the extent to which a participant's MBTI results predicted their survey responses, an M5 Model (M5P) decision tree correlated each participant's MBTI scores to each individual survey question [23]. M5P was selected for its ability to handle both categorical and numerical data as well as produce multiple linear regression models at the tree leaves. These results showed no significant correlation, although for the small sample of students who played the game regularly, responses were more positive than negative. With a sample this small, no significant conclusion can be drawn. Possible explanations for the lack of overall correlation include the game's lack of ties to the class, the number of responses from participants with fairly low playing time, a general lack of enjoyment from the game itself, or that the game was deployed after students had already established a routine for the class. Due to these factors, no causal relationship can be inferred, but evidence from this study suggests that the MBTI may not be a valid predictor of game enjoyment. More recent player typology tests that focus specifically on game mechanics may provide a better baseline for determining whether or not a player will enjoy a particular game.

A qualitative end-of-semester survey was administered to students, many of whom expressed interest in the idea of a class and game tied loosely together. Moving forward, it became apparent that the MBTI was not a great predictor for player typology in this setting, and my focus shifted to more specific player typologies. In addition, the MBTI was not cost-effective to administer, and this research shifted to focus on BrainHex, a much more specific player typology. Finally, with the MBTI's 16 subtypes, the sample size for each subtype was so small that it became difficult to draw meaningful conclusions.

4.6 CONCLUSION

From this study, we learned that there seems to be no evidence of improvement to students' self-reported learning in class when a game is deployed in class without ties back to class, although sample sizes were too small to determine whether this statement holds for each MBTI type. This allows future work to use this result as a baseline for determining how effective that game has been on students' self-reported learning. Future work at this stage was ready to incorporate initial ties back to class.

CHAPTER 5: RUNE CRAFTERS

5.1 INTRODUCTION

The major goals going into this study were to make the deployed game more fun than the previous implementation and thus more motivating to engage within this setting. We hypothesized that by introducing some basic effort-based ties back to class that we would begin to see some improvements in students' self-reported motivation and engagement in class. Due to a number of factors, including a delayed study start and the game not having enough content for extended engagement, results were mixed, but a couple notable findings show potential for the future of topic-independent gamification and are reason to continue exploring this research.

5.2 TECHNOLOGIES USED

This study was the first to be implemented using the Unity development engine. Code was written in C#, and the game was published using Unity's built-in web exporter. This was hosted on a university server, and data was collected and stored using MongoDB.

Player type analysis used the BrainHex [18,19] player typology, which rates players in 7 different types based on the game mechanics they enjoy. These are the Seeker, Survivor, Mastermind, Conqueror, Socializer, Daredevil, and Achiever.

- Seeker: Typically "curious about the game world and enjoy moments of wonder." They usually prefer games where they can explore and find "strange and wonderful things."

- Survivor: Enjoys experiencing terror, which has normally a negative appraisal. They like to escape from "hideous and scary threats," and take "pulse-pounding risks."
- Mastermind: These players "enjoy solving puzzles and devising strategies, as well as focus on making the most efficient decisions."
- Conqueror: These players are very challenge-oriented and they "enjoy defeating impossibly difficult foes, struggling until they achieve victory, and beating others."
- Socializer: Players fitting this archetype usually enjoy talking to other players, helping them, and interacting with players they trust.
- Daredevil: This play style is all about the rush, taking risks, and playing on the edge. They enjoy "dizzying platforms" and "rushing around at high speed."
- Achiever: These players are more goal-oriented and are motivated by long-term game achievements such as collecting special objects and amassing currency.

Each player receives scores in each of these archetypes based on Likert-scale survey questions, as well as a ranking question. The scoring algorithm for these questions is inconsistent across the literature, so I used a custom scoring method I validated by talking with the creators of BrainHex [18,19]. Factor analysis has also returned negative results for a few of the questions in the BrainHex survey, but it represents the best available tool for analysis of content-independent gamification.

5.3 GAMEPLAY

Rune Crafters was designed to be a crafting Role Playing Game, in which players explore the world, find secret areas, and fight monsters in real-time combat in order to improve their character (Figure 5), craft equipment (Figure 6), craft consumable items that heal or provide temporary bonuses for the player character, find item recipes, acquire skills, and level up. The five stats -- physical attack, physical defense, magical attack, magical defense, and speed -- control a character's physical damage, physical mitigation, magic damage, magic mitigation, and cooldown rates, respectively. Skills acquired from leveling up can be passive or active in nature. Passive skills apply their benefits at all times, whereas active skills can be used in or out of combat. Combat skills have a cooldown (based on the character's speed stat) to prevent them from being used too often. By progressing through the story, players can unlock different maps to explore. The story focuses on a town that has been hit hard by a plague, and only by defeating invading monsters can health be restored to the town. After initial forest zones, a mountain becomes accessible to explore.

5.4 METHODS

A Capstone project team of four undergraduate seniors was tasked with creating a crafting RPG called Rune Crafters with ties back to class in order to test whether or not the targeted Achiever BrainHex type would report more class motivation in the second half of the term when compared to students who were not Achievers.

A beta build of Rune Crafters was deployed in Washington State University's intro computer science classroom for majors during Spring 2016. An initial survey was given on the first day of class which produced a sample of 145 responses. This survey asked for basic demographic information as well as past gaming experience. Part of this survey was the official BrainHex survey, which determines a student's expressions for each of the seven BrainHex player types.

Figure 5: Rune Crafters battle system

Figure 6: Rune Crafters equipment screen

This study introduced the daily login code, an initial tie back to class. By attending class, students can discover a special code written on the whiteboard that is not given to those who miss class. When students log in to the game, in addition to their usual login credentials, there is a field for the daily login code, as shown in Figure 7. When the code has been successfully entered, students are rewarded with additional character progress that is otherwise unobtainable. The idea behind the daily login code is to motivate students to take outside action, such as attend class when they otherwise might not have in order to make additional progress in the game.

Figure 7: Rune Crafters login screen with daily login code

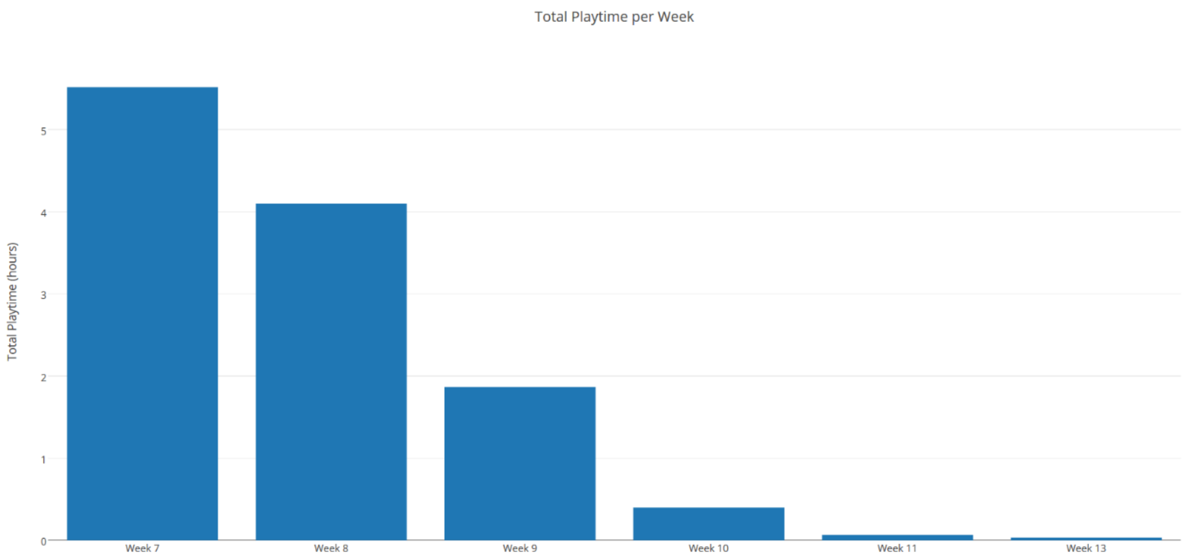

Figure 8: Total Rune Crafters playtime per week during follow up study

5.5 RESULTS AND DISCUSSION

On the eighth week of the semester, a second survey was deployed asking students how their motivation had changed throughout the semester, and the extent to which the game was motivating them. According to these surveys, 48% of the students who interacted with the game reported increased motivation at the time of the second survey compared to the first half of the semester, whereas the class average of players and non-players was only 20%. While this is a positive result, this in no way implies causation that Rune Crafters was the reason these students were experiencing increased motivation. In addition, 32% of the students who had Achiever as their top BrainHex expression played the game, whereas class-wide under 25% of the students engaged with the game. This can be attributed to the fact that the game's deployment was delayed by 3 weeks at the start of the semester to ensure there were minimal technical issues when students tried to play the game. However, the server still had issues logging player data during the first couple weeks of deployment. It is likely student engagement would have been higher if the game had been part of the course experience from the initial class.

As seen in Figure 8, player attrition was a large factor, as few people continued playing the game after the first few weeks. Note that the first couple weeks of the study are omitted from this chart because the server was not collecting data. This is likely attributable to the lack of game content and the fact that additional game mechanics were not staggered throughout the game. All participants had access to all game mechanics from the first day, and with more time for game development, it is likely that more engaging game mechanics could be introduced throughout the semester.

5.4 CONCLUSION

From this study, it became apparent that a timely deployment on the first day of class is necessary to ensure the maximum number of students play the game. Without becoming part of a student's routine early, it may feel like an added burden to modify an existing routine to add time for a game, which is contradictory to the purpose of this research. It may be possible to reduce player attrition, as seen in Figure 8, in future studies by ensuring timely game deployment. Additionally, the quality of the game was not similar to the quality of games students would play during their leisure time. It is possible any positive effect seen here would be magnified if the game were more fun and contained more content. Future work will prioritize enhancing the user's experience to whatever extent possible. Despite these shortcomings and lessons, there is enough evidence that TINGLE may be successful at increasing student motivation in class to continue trying to overcome these shortcomings.

CHAPTER 6: TIERED GAMES

6.1 INTRODUCTION

Continuing the development path laid out in chapter 5, it became apparent that in order to collect the best data, the deployed game must appeal to a wider audience and contain enough content to last an entire semester. This led to the development of a tiered game. A tiered game consists of multiple layers, each containing one or more games or minigames, where progress in a game or minigame in one tier affects progress in one or more games or minigames in another tier. By creating minigames designed to appeal to one particular BrainHex archetype, students would have the option to play any minigame at any time. This solves the issue in chapter 5 where our target audience was a small proportion of the class. With a sufficient number of minigames we could theoretically have at least one appealing minigame for each student. However, minigames are often not fun to play by themselves. They need glue to hold them together and to create the overall motivation to continue playing them. This is where an overarching game comes into play (Figure 8). I selected the incremental genre for the overarching game because of its accessibility, relatively easy implementation, and because it is inherently Achiever in nature. Incremental games are games whose gameplay consists of the player performing simple actions such as clicking on the screen repeatedly ("grinding") or making managerial decisions to earn currency. The Achiever BrainHex type is fairly consistently not the lowest scoring among the archetypes, meaning it is likely to be at least somewhat motivating to most students.

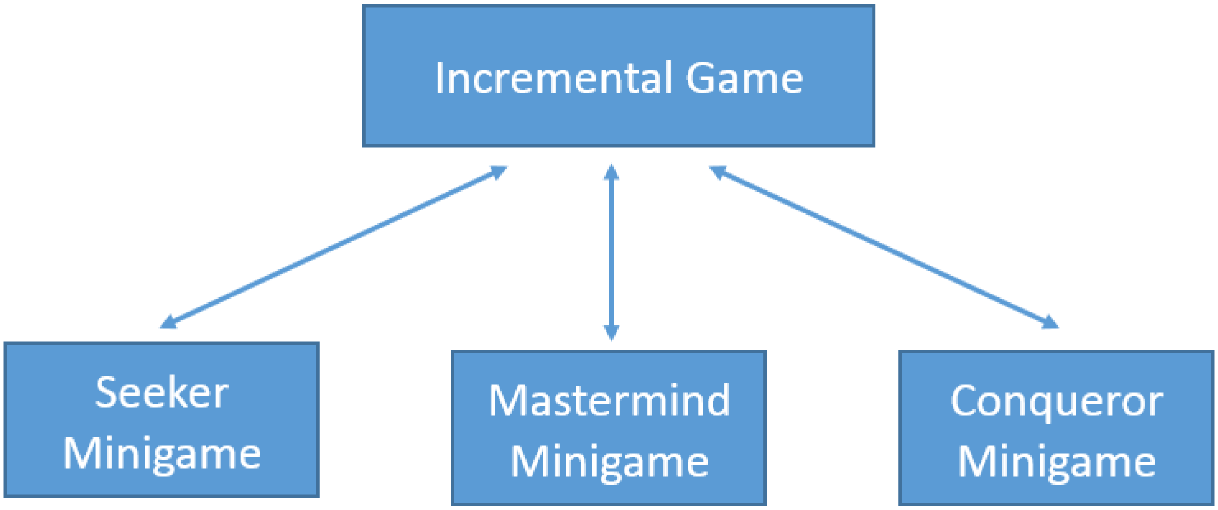

Figure 9: Tiered game architecture

6.2 GAMEPLAY

The game mechanics for this tiered game include many commonly associated with incremental games and prior gamification studies.

- Progress bar: Whereas most games tie a progress bar to a user-controlled activity such that it represents progress toward completion, in this game the progress bar fills up over time. When it reaches 100%, it is reset, and an amount of currency and experience is awarded to the player based on the mode that was active at the time.
- Experience: As the layer accumulates experience points from filling the progress bar, he/she levels up.
- Active/Passive: These are 2 togglable modes denoting whether the player is actively or passively playing the game. Progress is continuously made, even while the user is

offline. If the progress bar fills while in passive mode, less experience is awarded together with a few passive coins, which is one of the currencies. If the progress bar fills while in active mode, significantly more experience is awarded together with both active and passive coins. When the progress bar is in active mode, it also fills much faster. A user may only switch the progress bar to active mode if they have remaining active time, which is acquired through effort in class.

- Upgrades: Active and passive coins can be spent to purchase upgrades which can, for instance, increase the number of coins gained when the progress bar fills or increase the experience gained when the progress bar fills. Purchasing these upgrades significantly increases the progress made per unit of time.
- Ascension: Upon reaching level 50, students have the opportunity to ascend. In addition to a permanent bonus to experience gained, as well as active and passive coins gained, ascension resets all progress in the incremental. In addition, a permanent perk point is awarded, which can be used to purchase one of numerous upgrades in one of the many minigames.
- Progress between minigames and incremental: The minigames are all designed to award active and passive coins when played, and, as mentioned above, the incremental is designed to award progress in minigames when played. This creates an incentive for users to interact both with the incremental and one or more minigames.
- Stamina: The ability to play minigames such as the Seeker minigame (Figure 10) through the minigame selection screen (Figure 11), is gated behind stamina, which is gained through classroom effort. Without stamina or the aforementioned active time, students will be unable to acquire the active coins necessary for purchasing upgrades, thereby

stunting their progression. Additionally, without stamina, students cannot interact with the game at all. The goal is to reward players who apply classroom effort and fail to reward those who do not. It is not possible to interact with the game without applying effort in class.

- Leaderboard: Because some students may be unmotivated by a leaderboard, this is an opt-in mechanic. Those who do not wish to be displayed on a leaderboard or know their rank within the class can continue playing this game alone. But for those who are competitive, a leaderboard ranks students by ascensions completed and experience gained within ascensions. This rewards students who apply maximum effort in class and who play the game efficiently. It incentivizes intelligent use of time and resources.

Figure 10: Seeker minigame

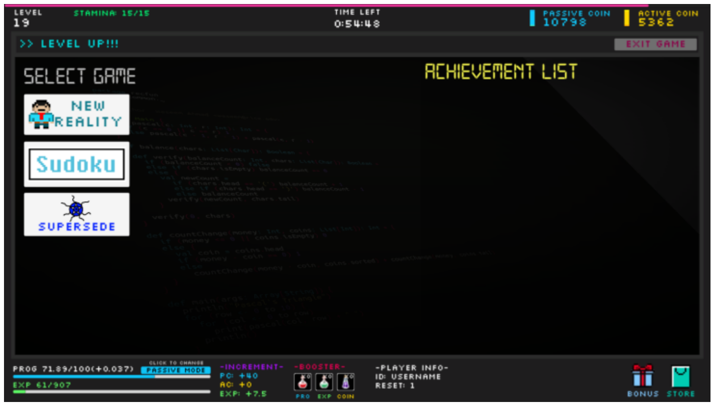

Figure 11: Minigame selection screen

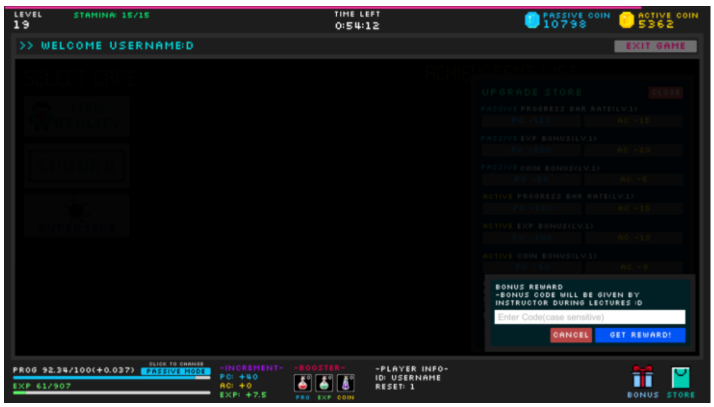

Figure 12: Bonus code field

While this system has yet to be fully tested in a classroom setting, arguments can be made for why it addresses the issues raised during prior research and aligns with all of TINGLE's goals.

This game design works well for a number of classroom effort measures. As before, a daily login code (Figure 12) can be used to measure attendance and engagement in class. In addition, progress can be given for completion and submission of homework problems. In a university setting, lab attendance and submission can also be used to award progress. Finally, grade trends can be analyzed, and students showing positive or neutral trends can be awarded a binary bonus. A server can be set up to collect the time spent in each minigame and the progress made in the incremental. Surveys can be used to gauge the success from the students' perspectives which may not be inherent in the data.

6.3 CONCLUSION

While the validity of this method has yet to be verified via an empirical study, which will be future work, the approach presented in this chapter has significantly more refined game mechanics than prior studies and a design that should be more accessible to larger proportions of the target audience. This will allow a larger sample size for the study to be conducted and remove the bias of targeting only a specific player type.

CHAPTER 7: PLAYER TYPOLOGY

7.1 INTRODUCTION

How to divide game players into groups based on their gaming preferences has been an open question for decades [2]. More than 150 million Americans play video games [1]. Thus, understanding why we play what we do and how we can use games in society has a widespread outreach. Game preferences are complex, containing psychological, social, and personality components. This makes it extremely difficult to derive a complete player typology that describes a large portion of the population, especially considering variables such as game experience because preferences can change rapidly as a person discovers what they like for the first time. To better understand player preferences, numerous models have been developed over the years with varying levels of success to attempt to explain why we like the games we like. This has numerous benefits, from advertising to game recommendation engines to creating better games for learning and motivation in classroom environments. By better understanding this relationship, it may be possible to provide better recommendations for users of diverse gaming backgrounds, increasing the effectiveness of many avenues of game research in non-game settings. Toward this end, it is important to validate existing models to show when they are or are not predictive. The goal of this section is to test one such model, BrainHex [18,19], in a setting similar to one of classroom learning, questioning the extent to which it can be used as a recommendation engine for serious games.

7.2 METHODS

To examine BrainHex's predictive ability, 14 college or graduate school students (12 male, 2 female, age range 18-33) with a variety of gaming tendencies played 10 games over 2 sessions. An introductory survey was given, asking participants about their prior gaming experience, and for demographic information and including the complete BrainHex survey. Three participants indicated they never or rarely play games, 3 more indicated they play games one or two days per week, 2 indicated they play games 3-5 days per week, and 6 indicated they play games daily. Due to a contradiction in the BrainHex literature with regard to how to score the survey, each question and ranking in the survey was given equal weight and scored by hand such that the minimum score for a category was 4 and the maximum was 22. The first session contained 7 games, of which each participant was randomly assigned 5 to play for 10 minutes in random order. The second session contained 5 games which each participant played for 10 minutes. All games were selected because they were casual, easy-to-access games that had simple gameplay and showcased their features within the first 10 minutes. In addition, we wanted to minimize the number of BrainHex categories under which each game fit, in order to better be able to predict the extent to which participants would enjoy them. As such, we selected both the games and corresponding BrainHex category/categories. The games used in both parts of the study are listed in Table 1. No Socializer games were chosen for this study because the archetype is difficult to isolate in a game setting. Socializer-heavy games get their gameplay from other archetypes and, as such, is more difficult than the others to measure.

Game Name	BrainHex Category/Categories
Part 1	
Cookie Clicker	Achiever
Dead Frontier: Outbreak	Survivor
Gravitee Wars Online	Conqueror
King’s League: Odyssey	Mastermind/Conqueror
Bloons TD 5	Mastermind
The Enchanted Cave 2	Seeker/Mastermind
Medieval Shorts 3	Seeker
Part 2	
Freeway Fury 2	Daredevil
Five Nights at Freddy’s	Survivor
Sort the Court	Achiever
Dinogen	Conqueror
Squarus	Mastermind

Table 2: Games used and associated BrainHex categories

After playing each game, participants were given a short survey about their experience. They ranked each game on a 5-point Likert scale, gave their current motivation level to continue participating in the study, and answered whether or not they had played this particular game or games like it before.

7.3 RESULTS AND DISCUSSION

To analyze the predictability of the BrainHex survey in this environment, the data collected was input to multiple machine learning algorithms using leave-one-out cross validation. Solely using a participant's BrainHex score for a game's assigned BrainHex category, the game name, and the participant's previously reported gaming frequency, we predicted the score a participant gave a game. The BrainHex score for the particular category was used because no other BrainHex category should be a factor in the game's rank. In the case where a game was assigned multiple BrainHex categories, the participants' BrainHex scores for each relevant category were averaged. The game name was included as a feature to attempt to learn larger game-wide trends. For instance, if a participant liked Seeker games, but a particular Seeker game was rated low by other participants (possibly due to the game being lower quality), it should be learnable that this particular game should have lower predicted scores, regardless of the participant's preference. Participants' prior gaming frequencies were used in case they were a factor in their overall scoring. Participants with less gaming experience might find certain games novel and rate them higher, whereas participants with more experience might have seen similar mechanics before, and be less inclined to find them fun. On the other hand, newer players might find certain mechanics unintuitive, whereas players with more experience might be able to jump in and understand the game mechanics faster, potentially leading to higher ratings.

First, each participant was left out in order to determine if an individual's game preferences could be learned solely from other participants' data. For each participant, each machine learning algorithm was trained on the other participants' results, then tested on the left-out participant. This would speak to the generalizability of these results and give an idea of the results we could expect on new unseen participants. The error measure used was the Mean Absolute Error (MAE), defined here to be:

$$MAE = \frac{\sum_{i=1}^{n}|y_i - x_i|}{n} = \frac{\sum_{i=1}^{n}|e_i|}{n}$$

The MAE was calculated to determine how well the algorithm could predict participants' game ratings. The MAE sums the absolute value of the differences between the actual and predicted values and divides this by the number of points, arriving at the mean error for each supervised learning algorithm on the data. MAE values close to 0 are best, showing small differences between the actual and predicted values. Large values of the MAE show that the learning algorithm was less able to predict the actual values accurately. Participants rated games on a 5-point Likert scale. Algorithms were implemented using Python's Pandas library. The algorithms used included:

- Logistic Regression [64] – A method for estimating the parameters of a logistic model, or one which has a binary output.
- Multilayer Perceptron [65] – A version of a feed-forward artificial neural network which is capable of differentiating non-linearly separable data.
- Naïve Bayes [66] - Uses Bayes' Theorem and independence assumptions between features to make predictions.
- Support Vector Machine (SVM) [67] - A non-probabilistic binary classifier that can regress non-linear data by mapping it into higher dimensional space.
- Decision Tree [68] – Uses entropy to determine which feature can be split to attain maximum information gain. Each node is a decision point with two or more children

representing a split of one of the features. By navigating the tree, one can classify or regress any input data.

The results of this experiment can be seen in Table 3.

Second, each participant/game pair was left out in order to determine whether or not prior experience with a particular participant's other game ratings were more predictive than the previous experiment. In this case, each algorithm was trained on all participant game/rating data, save one point, and tested on that single point. By allowing training on the other games of the test participant, we can see how much information is gained by training on prior experience, and use those results to show how useful it is to have future students play games and rate them before offering recommendations. The results of this experiment are also shown in Table 3.

Finally, similar to the prior experiment, each participant's other game ratings were boosted [69] to see if results improved when a larger portion of the training set were the other non-test game ratings from the same participant. Boosting is a technique that is useful when the potentially meaningful subset of the data represents a small portion of the data. By copying relevant data points, the learner will give those points more weight when determining the learning function. The data for each participant's other games were copied twice, thus appearing 3 times in the training set and making up approximately 20% of the training set. Table 3 displays these results.

Algorithm	Leave One Participant Out MAE	Leave One Game Out MAE	Boosted Leave One Game Out MAE
Logistic Regression	0.957	0.929	0.943
Multilayer Perceptron	0.943	0.936	0.943
Naïve Bayes	1.5	1.636	1.65
SVM	0.8	0.8	0.8
Decision Tree	0.9	0.835	0.91

Table 3: Supervised Learning Algorithm Results on Each Experiment

As final experiments, simple t-tests were performed to determine if participant self-reported motivation to continue with the study after playing each game and game rank are interrelated, as well as if the BrainHex score for each game's category and game rank are interrelated. The null hypotheses were that user-reported motivation to continue with the academic task came from the same distribution as the game ratings and that the transformed BrainHex scores came from the same distribution as the game ratings. After verifying that the difference between user-reported motivation and game rank was normally distributed (Figure 13), a t-test between them returned a p-value of <0.0001. For the BrainHex score, we transformed the raw user BrainHex scores to fit in the same range as the game rank (1-5), then ran a t-test. As before, the p-value was <0.0001.

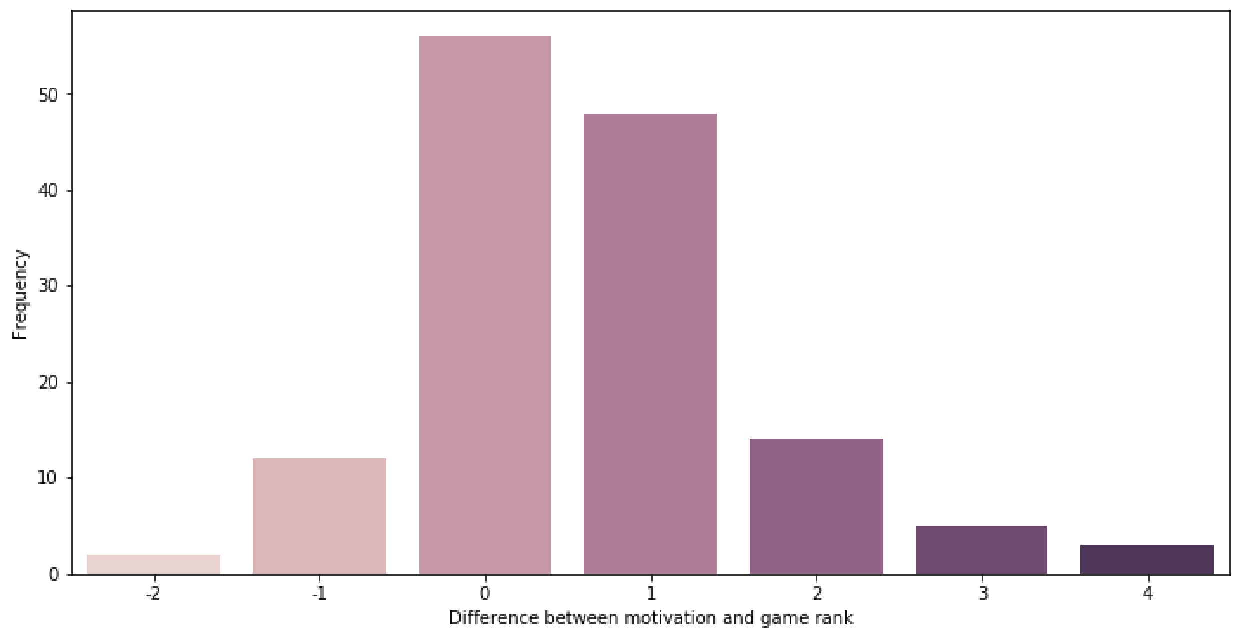

Figure 13: Frequency of the differences between motivation and game rank survey answers

Through these t-tests it has become apparent that, in this setting, BrainHex struggles to accurately predict game ratings based on the survey provided. Even the best machine learning approach, the SVM, had large mean absolute errors, considering the frequency of higher ratings overall compared to the lower ratings. The overall number of times each game rating 1-5 was given was [9,11,34,57,29] respectively. The large errors in the leave-one-person-out experiment indicate that it is difficult to predict how a participant will score a game solely from other participants' data and the BrainHex survey results.

Despite this, one would assume that the prediction would be easier once we include data from the participant's other games. It is intuitive to believe that data from the participant we are trying to predict would be more predictive than data from strangers, but results show minimal, if any, improvement once this data is added to the model. Following this logic, boosting the participant's other results would amplify the effect, possibly leading to increased predictability.

But as the results show here, again there is no real improvement in the model's predictability. This leads to the conclusion that BrainHex scores are not indicative of how participants scored these games.

Finally, both t-tests were significant, showing an extremely high probability the input features are from separate distributions, even after normalization. This can be seen in Figure 14, where participants often gave a higher motivation score than they gave a game rank. Yet it seems there may be something here, as instances where motivation was low corresponded to having recently played games that received a low rating. Because of the limited sample size of games rated low, and the fact that these came from just a few of the participants, further data and research are necessary to draw any concrete conclusions. Similarly, despite the t-tests returning significant results, a trend is visible within the BrainHex data. Figure 15 shows the mean BrainHex score of participants for each rank given. Intuitively, if a user gave a higher rating to a game, it follows that they had a higher BrainHex score for that category. Due to the limited sample of participants rating games a 1 or 2, the result for 2 may be an anomaly, and further testing is required.

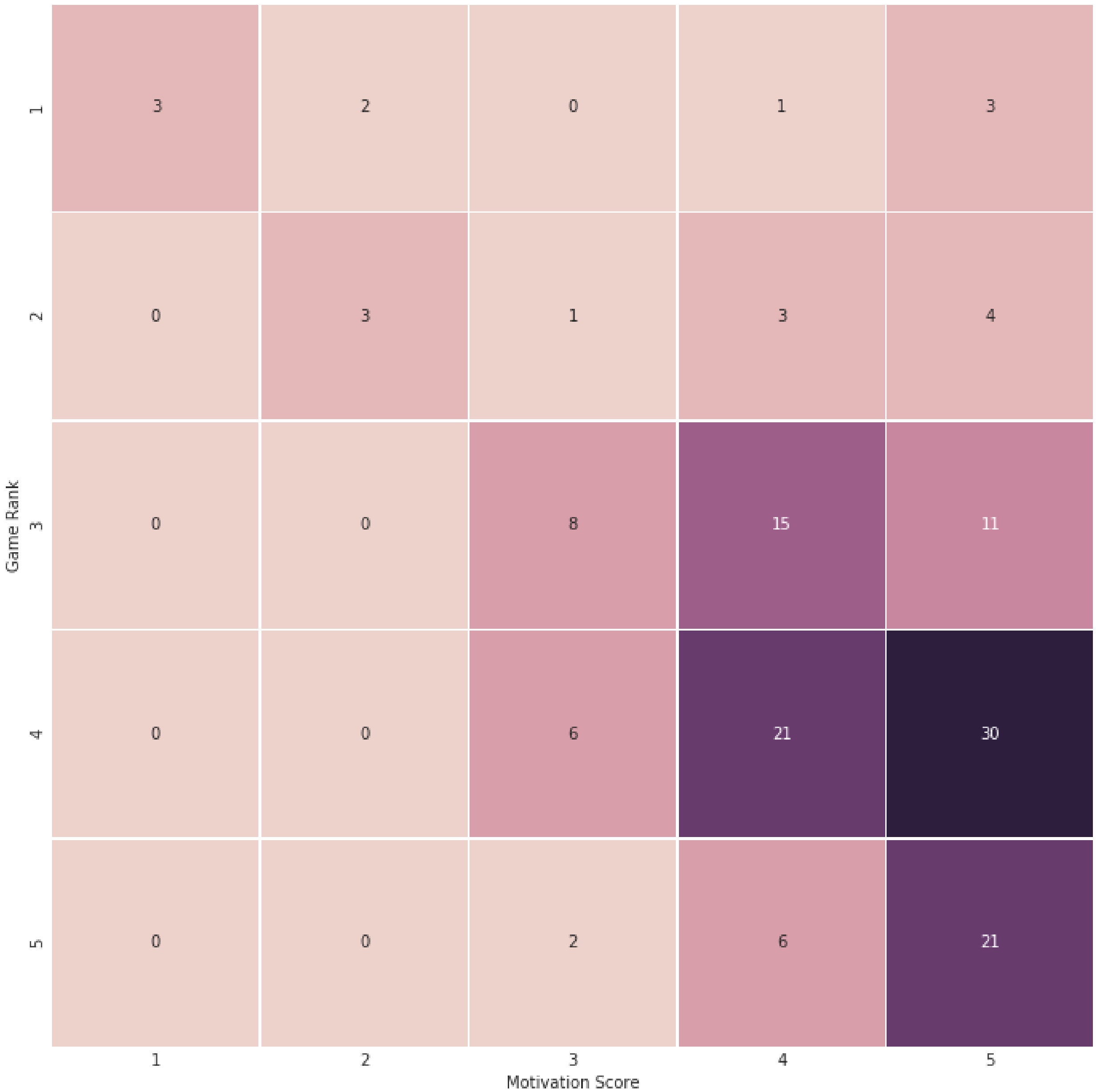

Figure 14: Heatmap of game rank/motivation data

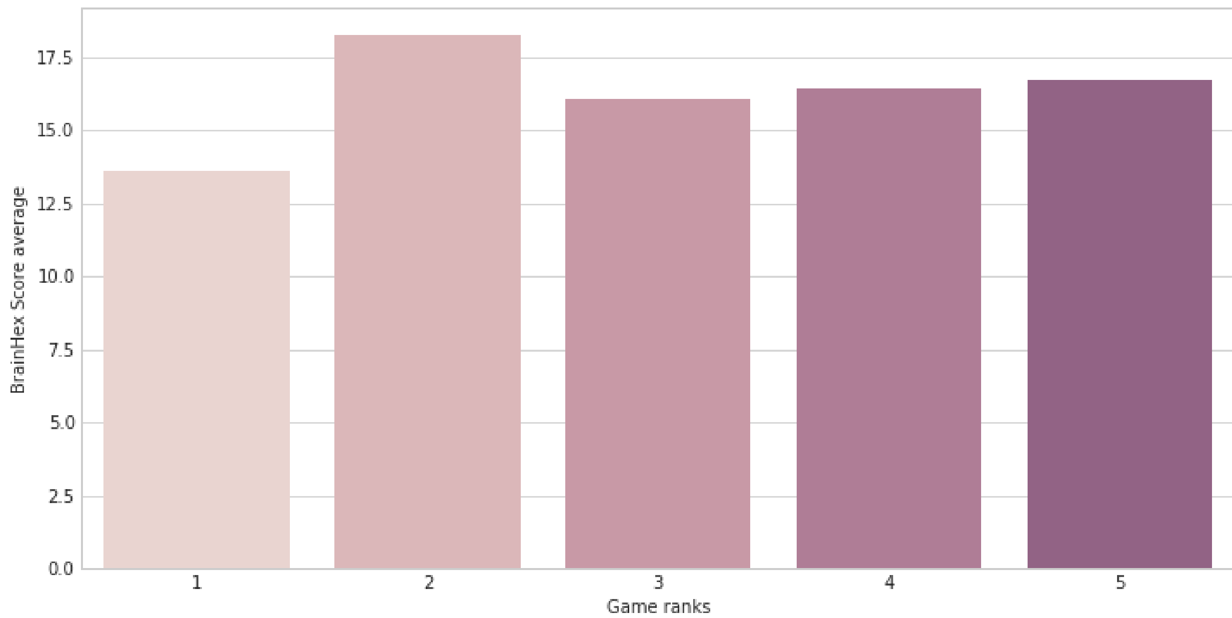

Figure 15: Average BrainHex score for each game rating

There are a number of limitations to this study. First, due to scoring inconsistencies among BrainHex literature and upon emailing the creators and receiving a response that indicated they did not know which scoring method to use, we were forced to determine our own scoring methodology for the BrainHex survey. While priority went to giving questions equal weight, this may not be the optimal scoring method for the questions, and this may have led to suboptimal results. A limited sample size is also worth noting. With only 14 participants, any outlier preferences have the ability to throw off the model. If the differences in prior gaming experience were a factor, the limited sample size is especially apparent. Additionally, each game was only played for 10 minutes in order to keep the study a reasonable length. However, 10 minutes may not have been enough time for participants to truly grasp the gameplay. While every effort was made to select games that were simple enough to grasp quickly, there are potential biases related to both the limited duration affecting participants' ratings in a way that's inconsistent with their BrainHex results and the selection of the games' BrainHex categories.

Future work in this area involves significantly more testing and validation, especially with larger sample size studies. Much more work needs to be done to be able to say for certain whether or not modern player typologies are generalizable and predictive. This avenue of research could lead to advances in areas such as classroom gamification, where it is especially important to have high quality game recommendations because poor recommendations have the possibility of detracting from motivation and have significant adverse effects.

7.4 CONCLUSION

By looking at the predictability and generalizability of player type models, we can begin to validate their use in specific settings such as casual game rating prediction. This work looked at one such model, BrainHex, and determined that in this limited study and environment, it failed to adequately predict participant game ratings and as such may not be useful as a predictor in fields such as classroom gamification the way it is currently structured. Much more work is needed to validate these claims, and this section is just a starting point.

CHAPTER 8: CONCLUSIONS

8.1 SUMMARY OF WORK

In this dissertation I have presented three studies related to topic-independent classroom gamification. The first two address the implementation of how to successfully develop and deploy a game with no content integration in the gameplay itself outside of class. The first included no ties back to curricular effort and established a baseline for the motivational effect of a content-independent game. Due to this lack of motivational effect, one can compare future similarly constructed studies to a baseline of no effect. The second study implemented basic ties to curricular effort, although with a limited target audience, and showed evidence that TINGLE's approach may be successful when the game targets their gaming preferences. Work since then has focused on expanding the scope of TINGLE to incorporate more diverse gaming interests and on improving the game experience for future studies. The final study focused on predicting game preference based on survey results and quick gaming sessions. By isolating the survey and game aspects of the study, the extent to which each contributes to the overall predictability of game preference was shown. This will help inform future implementations of TINGLE and maximize the chance that TINGLE can be effective for each student because playing a game that's not motivating may have a neutral or detrimental effect on their motivation. This dissertation lays the groundwork for future work analyzing and improving upon this methodology with the goal of increasing student motivation through the use of extrinsically motivating games.

8.2 LIMITATIONS

TINGLE's development and initial deployment have had several limitations that will be acknowledged and addressed in this section. The biggest limitation in this research to date has been the limited pool of participants in studies. Due to deployment in introductory computer science and construction management/civil engineering classrooms, the students playing the games that have made up TINGLE's studies to date have been biased based on those who would be interested in taking these classes in the first place. These students are likely to play games in their own free time and have existing game playing experience before playing TINGLE's games. This may decrease their overall interest in TINGLE because they may have played similar or better games before. It may increase their interest in TINGLE because it aligns with their natural hobbies and interests. Additionally, computer science classes have a disproportionate number of males, skewing my results toward the preference of males. I plan to address this in future work and would like to tailor my game development to include preferences of a wider variety of students in diverse disciplines of study.

A couple of my studies have had a limited sample size, possibly influencing the results. Larger classes naturally have more diversity within their population, allowing increased diversity when used as a sample. By deploying this research in larger and more diverse classes, I should be better able to quantify TINGLE's motivational effect in the aggregate.

Thus far in my research, I have only been able to deploy TINGLE in college classes. The motivational effect of TINGLE's approach has not been tested on K-12 students, as I have been waiting for positive results on college students before attempting to get my research in K-12 classrooms where parental permission will be required. It is more likely to succeed if parents can see the positive effect it can have on college students and will be more likely to sign off on allowing their children to interact with TINGLE.

TINGLE studies so far have been carried out at most over one semester. The extent to which TINGLE's motivation extends beyond that time has yet to be tested, and this is important to understand when developing games and learning interventions. Coming up with a methodology for detecting when a game is starting to lose its motivational effect in class and an intervention for recovering it will be an important part of future research, but for now it is a relative unknown.

8.3 IMPACT

TINGLE has a wide range of potential impacts. For students, it has the potential to increase their ability to focus, learn, and retain class material. The ability to keep students engaged in their learning atmosphere is vital to their understanding of the learning content. This benefit extends to instructors as well in the form of students who may be easier to teach or more receptive to their teaching styles. By spending less time repeating themselves for students who struggled to find the motivation to engage in class, more class time can be dedicated to teaching and learning. TINGLE is a form of gamification that does not distract during class time, again improving classroom productivity over alternative gamification methods.

Beyond the classroom, this methodology has not been explored in a workplace or personal improvement setting. While workplace gamification has shown to be effective, little has been done to measure the extent to which it is also a distraction. Refinements of this technique may be applicable to increasing the productivity of workers since there often are not very effective performance bonuses. Companies would love to deploy a performance bonus that neither costs them each time it is deployed (like a pay bonus) and is customizable to employee preferences.

8.4 FUTURE WORK

Moving forward with TINGLE, the first priority is improving the game quality. By approaching the level of quality students expect from a game they have purchased, player engagement and retention will increase, hopefully also increasing the motivation level and duration for the ties to class. This involves adding additional game mechanics and refining the ones already in place. To accomplish this, feedback will be acquired from students who take part in studies, and their suggestions will be prioritized and implemented.

TINGLE only currently has support for 3 minigames: the seeker-based minigame, the conqueror-based minigame, and the mastermind-based minigame. Plans are in place to add additional minigames for more BrainHex player types including the speed-loving daredevil and the fear-loving survivor. I also plan to expand and create additional minigames for puzzle lovers. By giving students even more options for minigames to play, I hope to appeal to a wider variety of player preferences.

Because TINGLE has only been tested in classrooms in computer science and construction management, it is still relatively unproven to a number of demographics. Both the previously mentioned fields have more men than women, and it is a priority to develop games that are as effective for women as they are for men. To determine TINGLE's effectiveness on women, I intend to pay extra attention to feedback from women in the classes TINGLE has been deployed in as well as to prioritize adding women to TINGLE's development team. In addition, I plan to study the effectiveness of external games as motivators for students of various socioeconomic and cultural backgrounds, especially those for whom English is not their first language. This work would serve to increase the accessibility of TINGLE and to not prioritize some students over others.

As TINGLE has only been deployed in classrooms from a couple disciplines, I plan to continue to deploy this research in classrooms of different disciplines. The type of personality you see in an English classroom is very different from one you see in a computer science classroom. As such, it is worth investigating differences in effectiveness between them. In addition, TINGLE is completely untested on students in K-12 environments. Future work would see studies between different age groups, possibly with different games or mechanics, to see if there is a difference in motivation. Once that has been established, a longitudinal study following students throughout their development could be useful to see how their preferences change with age, and whether we can identify the points where a particular game becomes less motivating, and whether there is an intervention that can recover some or all of that lost motivation. This may come from switching the game the student is playing, possibly carrying some of their progress from the prior game through to the new one.

Future work may also explore additional methods of measuring student effort. As smart health technology becomes more effective, it may be possible to use eye tracking or voice recognition to measure in-class effort. For instance, eye tracking can tell whether a student is looking at the instructor or at the clock. Voice recognition can be tuned to a specific student's voice and can tell the volume and intonation of their voice. Are they talking to the class or to their neighbor? Is what they are saying on topic or is it complaining about a hangover? Video may also be able to capture repetitive motion or anxiety in students. Any or all of these can be data points in helping us understand what works or does not work for certain students, and what attention and focus look like.

I also plan to continue work on game recommendation in this setting. I would like to run a study with a larger sample size to get sufficient results for players of many backgrounds and player preferences. The key to motivating students who say they do not like games is to recommend the right game.

Finally, I plan to incorporate additional research on player types as it is published. Player type research still has a way to go before we fully understand the motivations behind player preferences, but as we learn more, it will only make TINGLE stronger.

8.5 CONCLUDING REMARKS

This dissertation has introduced TINGLE and documented its development, validation, and current iteration. While there is much work to be done in the fields of content-independent classroom gamification and player typology development and analysis, the studies presented in this dissertation are first steps toward a complete and validated model.

BIBLIOGRAPHY

[1] Erenli, K., 2012, September. The impact of gamification: A recommendation of scenarios for education. In *Interactive Collaborative Learning (ICL), 2012 15th International Conference on* (pp. 1-8). IEEE.

[2] Hamari, J., Koivisto, J. and Sarsa, H., 2014, January. Does gamification work?--a literature review of empirical studies on gamification. In *System Sciences (HICSS), 2014 47th Hawaii International Conference on* (pp. 3025-3034). IEEE.

[3] Kapp, K.M., 2012. *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons.

[4] Balasubramanian, N. and Wilson, B.G., 2006. Innovative methods of teaching science and engineering in secondary schools. *Inquiry*, *1*, p.2.

[5] Lenhart, A., Kahne, J., Middaugh, E., Macgill, A.R., Evans, C. and Vitak, J., 2008. Teens, video games, and civics: teens' gaming experiences are diverse and include significant social interaction and civic engagement. *Pew internet & American life project*.

[6] Deci, E.L., Koestner, R., Ryan, R.M., 1999. A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. Psychol. Bull. 125, 627.

[7] Ryan, R.M., 2012. The Oxford Handbook of Human Motivation. Oxford University Press. Oxford, UK.

[8] Zichermann, G., 2011. Intrinsic and Extrinsic Motivation in Gamification [WWW Document]. Gamification Co. URL: http://www.gamification.co/2011/10/27/intrinsic-and-extrinsic-motivation-in-gamification/

[9] Denny, P., 2013. The effect of virtual achievements on student engagement. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. Presented at CHI13. ACM, pp. 763–772.

[10] Domínguez, A., Saenz-de-Navarrete, J., de-Marcos, L., Fernández-Sanz, L., Pagés, C., Martínez-Herráiz, J.-J., 2013. Gamifying learning experiences: practical implications and outcomes. Comput. Educ. 63, 380–392.

[11] Bateman, C., Lowenhaupt, R. and Nacke, L.E., 2011, September. Player typology in theory and practice. In *Proceedings of DiGRA*.

[12] Felder, R.M., Felder, G.N. and Dietz, E.J., 2002. The effects of personality type on engineering student performance and attitudes. *Journal of engineering education*, *91*(1), pp.3-17.

[13] Keirsey, D. and Bates, M.M., 1984. *Please understand me*. Prometheas Nemesis.

[14] Myers-Briggs, I., 1962. The Myers-Briggs type indicator manual. *Prinecton, NJ: Educational Testing Service*.

[15] Bartle, R., 1996. Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD research*, *1*(1), p.19.

[16] Bateman, C. and Boon, R., 2005. *21st Century Game Design (Game Development Series)*. Charles River Media, Inc.

[17] Buss, A.H. and Plomin, R., 1975. *A temperament theory of personality development*. Wiley-Interscience.

[18] Nacke, L.E., Bateman, C. and Mandryk, R.L., 2011, October. BrainHex: Preliminary Results from a Neurobiological Gamer Typology Survey. In *ICEC* (pp. 288-293).

[19] Nacke, L.E., Bateman, C. and Mandryk, R.L., 2014. BrainHex: A neurobiological gamer typology survey. *Entertainment computing*, *5*(1), pp.55-62.

[20] De Freitas, A.A. and de Freitas, M.M., 2013. Classroom Live: a software-assisted gamification tool. *Computer Science Education*, *23*(2), pp.186-206.

[21] Featherstone, G., Aston, H. and Houghton, E., 2013. *Game-based learning: Latest evidence and future directions*. Slough: NFER.

[22] Deterding, S., Björk, S.L., Nacke, L.E., Dixon, D. and Lawley, E., 2013, April. Designing gamification: creating gameful and playful experiences. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 3263-3266). ACM.

[23] Wang, Y. and Witten, I.H., 1996. *Induction of model trees for predicting continuous classes* (pp. 128-137). Department of Computer Science, University of Waikato.

[24] Seaborn, K. and Fels, D.I., 2015. Gamification in theory and action: A survey. *International Journal of Human-Computer Studies*, *74*, pp.14-31.

[25] "Classcraft." IBM - United States. July 2017. Accessed March 21, 2018. https://www.ibm.com/case-studies/s926156k98494l93.

[26] "Why Use Gamification in the Classroom?" Classcraft. 2017. Accessed March 21, 2018. https://www.classcraft.com/overview/.

[27] Papadakis, Stamatios, and Michail Kalogiannakis. "Using Gamification for Supporting an Introductory Programming Course. The Case of ClassCraft in a Secondary Education Classroom." In *Interactivity, Game Creation, Design, Learning, and Innovation*, pp. 366-375. Springer, Cham, 2017.

[28] Calvo, A., Rotaru, D.C., Freire, M., Fernandez-Manjon, B.: Tools and Approaches for

Simplifying Serious Games Development in Educational Settings. In: Global Engineering Education Conference (EDUCON), pp. 1188-1197. IEEE(2016).

[29] Sanchez, E., Young, S., Jouneau-Sion, C.: ClassCraft: From Gamification to Ludicization of Classroom Management. Education and Information Technologies, 1-17 (2016).

[30] Barata, G., Gama, S., Jorge, J., Goncalves, D.: Engaging Engineering Students with Gamification. In: 5th International Conference on Games and Virtual Worlds for Serious Applications, pp. 1–8 (2013).

[31] Berkling, K., Thomas, C.: Gamification of a Software Engineering Course. In: International Conference on Interactive Collaborative Learning, pp. 525–530 (2013).

[32] Brewer, R., Anthony, L., Brown, Q., Irwin, G., Nias, J., Tate, B.: Using Gamification to Motivate Children to Complete Empirical Studies in Lab Environments. In: 12th International Conference on Interaction Design and Children, pp. 388–391 (2013).

[33] Eleftheria, C.A., Charikleia, P., Iason, C.G., Athanasios, T., Dimitrios, T.: An Innovative Augmented Reality Educational Platform using Gamification to Enhance Lifelong Learning and Cultural Education. In: 4th International Conference on Information, Intelligence, Systems and Applications, pp. 1–5 (2013).

[34] Gibson, D., Ostashewski, N., Flintoff, K., Grant, S., Knight, E.: Digital Badges in Education. Education and Information Technology. Springer, New York (2013).

[35] Goehle, G.: Gamification and Web-based Homework. Problems, Resources, and Issues in Mathematics Undergraduate Studies 23(3), 234–246 (2013).

[36] Kapp, K.M.: Games, Gamification, and the Quest for Learner Engagement. Training and Development 66(6), 64–68 (2012).

[37] Kumar, B., Khurana, P.: Gamification in Education – Learn Computer Programming with Fun. International Journal of Computers and Distributed Systems 2(1), 46–53 (2012).

[38] O'Donovan, S., Gain, J., Marais, P.: A Case Study in the Gamification of a Universitylevel Games Development Course. In: Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference, pp. 242–251 (2013).

[39] Raymer, R.: Gamification - Using Game Mechanics to Enhance eLearning. eLearn Magazine (2011), http://elearnmag.acm.org/featured.cfm?aid=2031772.

[40] Santos, C., Almeida, S., Pedro, L., Aresta, M., Koch-Grunberg, T.: Students' Perspectives on Badges in Educational Social Media Platforms: The Case of SAPO Campus Tutorial Badges. In: IEEE 13th International Conference on Advanced Learning Technologies, pp. 351–353 (2013).

[41] Todor, V., Pitică, D.: The Gamification of the Study of Electronics in Dedicated E-learning Platforms. In: 36th International Spring Seminar on Electronics Technology, pp. 428–431 (2013).

[42] Villagrasa, S., Duran, J.: Gamification for Learning 3D Computer Graphics Arts. In: First International Conference on Technological Ecosystem for Enhancing Multiculturality, pp. 429–433 (2013).

[43] Ip, B., & Jacobs, G. (2005). Segmentation of the games market using multivariate analysis. Journal of Targeting, Measurement and Analysis for Marketing, 13(3), 275-287. Jansz, J. & Tanis, M. (2007). Appeal of Playing Online First Person Shooter Games. CyberPsychology & Behavior, 10(1), 133-136.

[44] Stewart, B. (2011). Personality And Play Styles: A Unified Model. http://www.gamasutra.com/view/feature/6474/personality_and_play_styles_a_.php.

[45] Drachen, A., Canossa, A., & Yannakakis, G., N. (2009). Player Modeling using SelfOrganization in Tomb Raider: Underworld. Proceedings of the IEEE Symposium on Computational Intelligence and Games.

[46] Yee, N. (2002). Facets: 5 Motivation Factors for Why People Play MMORPG's. Available at: http://www.nickyee.com/facets/home.html.

[47] Yee, N. (2006). The Demographics, Motivations and Derived Experiences of Users of Massively Multi-User Online Graphical Environments. PRESENCE: Teleoperators and Virtual Environments, 15, 309-329.

[48] Yee, N. (2007). Motivations of Play in Online Games. Journal of CyberPsychology and Behavior, 9, 772-775.

[49] Keirsey, David, and Marilyn M. Bates. *Please understand me*. Prometheas Nemesis, 1984.

[50] Zackariasson, P., Wåhlin, N., & Wilson, T.L. (2010). Virtual Identities and Market Segmentation in Marketing in and Through Massively Multiplayer Online Games (MMOGs). Services Marketing Quarterly, 31, 275–295.

[51] Tseng, F-C. (2010). Segmenting online gamers by motivation. Expert Systems with Applications, 38, 7693–7697.

[52] Leo Whang, S.M., & Lee, S.J. (2004). Lifestyles of Virtual World Residents: Living in the On-Line Game “Lineage”. CyberPsychology & Behavior, 7(5), 592-600. Selwyn, N. (2007). Hi-tech = Guy-tech? An exploration of undergraduate students’ perceptions of information and communication technologies. Sex Roles, 56, 525–536.

[53] Kallio, K.P., Mäyrä, F., & Kaipainen, K. (2011). At Least Nine Ways to Play: Approaching Gamer Mentalities. Games and Culture, 6(4), 327-353

[54] Nicholson, Scott. "A recipe for meaningful gamification." In *Gamification in education and business*, pp. 1-20. Springer, Cham, 2015.

[55] Stott, Andrew, and Carman Neustaedter. "Analysis of gamification in education." *Surrey, BC, Canada* 8 (2013): 36.

[56] Nah, Fiona Fui-Hoon, Qing Zeng, Venkata Rajasekhar Telaprolu, Abhishek Padmanabhuni Ayyappa, and Brenda Eschenbrenner. "Gamification of education: a review of literature." In *International conference on hci in business*, pp. 401-409. Springer, Cham, 2014.

[57] Hamari, Juho, and Janne Tuunanen. "Player types: A meta-synthesis." *Transactions of the Digital Games Research Association* 1, no. 2 (2014).

[58] Ryan, Richard M., and Edward L. Deci. "Intrinsic and extrinsic motivations: Classic definitions and new directions." *Contemporary educational psychology* 25, no. 1 (2000): 54-67.

[59] Rozeboom, R. (Producer) (2012). Professor Clifford Lampe Talks About Gamification in Academia. [video file] Retrieved from http://tinyurl.com/c8o4j7d

[60] Microsoft Research (n.d.). Just Press Play. Retrieved from http://research.microsoft.com/en-us/projects/justpressplay

[61] Habatica – Gamify Your Life. https://habitica.com/static/home

[62] Picnic™ BasKit - the ultimate gamified engagement, loyalty & contesting package. https://www.picnicengine.com/picnic-baskit

[63] Briggs, Katharine C. Myers-Briggs type indicator. Palo Alto, CA: Consulting Psychologists Press, 1976.

[64] Cramer, Jan Salomon. "The origins of logistic regression." (2002).

[65] Ruck, Dennis W., Steven K. Rogers, Matthew Kabrisky, Mark E. Oxley, and Bruce W. Suter. "The multilayer perceptron as an approximation to a Bayes optimal discriminant function." IEEE Transactions on Neural Networks 1, no. 4 (1990): 296-298.

[66] Zhang, Harry. "The optimality of naive Bayes." AA 1, no. 2 (2004): 3.

[67] Boser, Bernhard E., Isabelle M. Guyon, and Vladimir N. Vapnik. "A training algorithm for optimal margin classifiers." In Proceedings of the fifth annual workshop on Computational learning theory, pp. 144-152. ACM, 1992.

[68] Breiman, Leo. Classification and regression trees. Routledge, 2017.

[69] Schapire, Robert E. "The strength of weak learnability." Machine learning 5, no. 2 (1990): 197-227.

[70] Cordova, Diana I., and Mark R. Lepper. "Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice." Journal of educational psychology 88, no. 4 (1996): 715.

[71] McGonigal, Jane. Reality is broken: Why games make us better and how they can change the world. Penguin, 2011.

[72] Perryer, Chris, Nicole Amanda Celestine, Brenda Scott-Ladd, and Catherine Leighton. "Enhancing workplace motivation through gamification: Transferrable lessons from pedagogy." The International Journal of Management Education 14, no. 3 (2016): 327-335.

[73] Chatfield, Tom. Fun Inc.: Why gaming will dominate the twenty-first century. Open Road Media, 2011.

APPENDIX: LIST OF PUBLICATIONS

Journal Articles

[1] Alinia, Cain, Fallahzadeh, Shahrokni, Cook, and Ghasamzadeh. *How Accurate Is Your Activity Tracker? A Comparative Study of Step Counts in Low-Intensity Physical Activities.* Journal of Medical Internet Research Mhealth Uhealth Vol. 5 Iss. 7. (2017)

[2] Cain, Anderson and Taylor. *Content Independent Classroom Gamification*. American Society of Engineering Education Computers in Education Journal Vol. 7 No. 4. (2016)

[3] Hajiamini, Shirazi, Cain, and Hong. *Optimal Energy-Aware Scheduling in VFI-enabled Multicore Systems*. IEEE High Performance Computing Clusters 17 (2017)

Conference Proceedings

[4] Cain, Anderson and Taylor. *Work in Progress - Content Independent Classroom Gamification.* American Society for Engineering Education Annual Conference. (2016)

Workshop Papers

[5] Simon, Cain, Hajiamini, Saeedi, Schmitter-Edgecomb, Cook. *Digital memory notebook: experimental evaluation of motivational reward strategies.* Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing. (2014)