

# **ACADEMIA ARCANA: A GAMIFIED AND GAME-BASED REVIEW TOOL**

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A Thesis Presented to  
the Faculty of the Department of Computer Science  
University of Houston

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In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science

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By  
Mayur Thangadurai Rajendran

May 2016

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# Acknowledgements

To my father, Rajendran Thangadurai and mother, Bagya Latha Rajendran, for their support and belief in me. They helped me find the strength to get things done, even when the odds were overwhelming.

To my sister, Mahitha, for always being there, whenever I needed her. Without her support and encouragement, I would be lost.

To my twin, Madhur, whose ideas and contributions gave life to this project. Without him by my side, I would be incomplete.

To Adi, Vish and Shiv, because you don't need to be related to be brothers.

I would like to express my extreme gratitude to my advisor, Dr. Zhigang Deng. He gave me a chance and helped me develop my ideas into a project.

I would also like to thank Dr. Nouhad Rizk, a member of my committee, for allowing me to launch my project in her class and providing everything I needed at every step of the way.

I would like to thank my other committee members, Dr. George E. Fox and Dr. Weidong Shi, who took the time to review my thesis and provide their valuable insights.

Finally, I would like to thank all the students in all the classes I have been a Teaching Assistant for, those that played the game and those that did not.

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# Abstract

One of the main issues faced by students in college courses is the lack of motivation towards reviewing the subject material. While there have been many advances in the fields of gamification (of educational material) and game-based learning, that may help, each of these processes are different in their implementations and goals. However, it is believed that when combined, both of these different fields can complement each other in a way that creates a more powerful learning environment.

In this thesis, a preliminary research study of how game-based learning and gamification can be effectively combined to provide an engaging tool for review that college students can use during an actual semester is shown. Specifically, this project is split into two parts.

The first is the development of a novel education tool to help and motivate college students to better review course materials by engaging them in the form of a game. The tool is designed for the Computer Organization and Programming course and will allow students to take on the role of a character in order to progress through the game. As they advance, their character will gain levels and change along with their comprehension of the material they are studying. If students cannot answer questions to prove their understanding on a particular topic, they will be stuck in that part of the game until they are able to do so.

Second is a study based on student's use of the game during regular college semesters. Based on the outcome of the study, it is seen that our tool can be used as an additional effective form of review of course materials. While it can effectually augment traditional teaching methods, it is not meant to replace them.

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Problem Statement . . . . .	1
1.2	Contribution . . . . .	2
1.3	Outline . . . . .	3
<b>2</b>	<b>Background</b>	<b>4</b>
2.1	Gamification . . . . .	4
2.1.1	Points . . . . .	6
2.1.2	Rewards . . . . .	6
2.1.3	Competition . . . . .	6
2.2	Game-Based Learning . . . . .	7
2.3	Gamification in a Game-Based Environment . . . . .	8
2.4	Development . . . . .	10
2.4.1	Platform . . . . .	10
2.4.2	Setting . . . . .	11
2.4.3	Gamification of Course . . . . .	11
2.4.4	Game-Based review . . . . .	12
<b>3</b>	<b>Academia Arcana</b>	<b>13</b>
3.1	Game Goal . . . . .	14

3.2	Gameplay . . . . .	14
3.2.1	Accessing the Game . . . . .	14
3.2.2	Character Creation . . . . .	15
3.2.3	Controls . . . . .	15
3.2.4	Character Screen . . . . .	16
3.2.5	Quests . . . . .	18
3.2.6	Battles . . . . .	19
3.2.7	NPCs . . . . .	22
3.2.8	Enemies . . . . .	23
3.2.9	Bosses . . . . .	25
3.3	Website . . . . .	27
3.3.1	Profile . . . . .	28
3.3.2	Leaderboards . . . . .	30
3.3.3	News/Updates . . . . .	30
3.4	Question Generation . . . . .	31
<b>4</b>	<b>Research and Methodologies</b>	<b>32</b>
4.1	Game Inspired Research Methods . . . . .	34
4.1.1	Creating a Community . . . . .	34
4.1.2	Personalized Goals . . . . .	34
4.1.3	Intuitive Controls . . . . .	35
<b>5</b>	<b>Results</b>	<b>36</b>
5.1	Summer 2015 Semester . . . . .	37
5.1.1	Students Who Played the Game . . . . .	38
5.1.2	Students Who Did Not Play the Game . . . . .	39
5.1.3	Comparison Between Both Groups . . . . .	40

5.2	Fall 2015 Semester . . . . .	41
5.2.1	First Exam . . . . .	41
5.2.2	Final Exam . . . . .	43
5.3	Discussion and Observations . . . . .	45
<b>6</b>	<b>Conclusion</b>	<b>47</b>
6.1	Future Work . . . . .	47
	<b>Appendices</b>	<b>49</b>
<b>A</b>	<b>User Details</b>	<b>50</b>
<b>B</b>	<b>Decimal To Binary Conversions Performance</b>	<b>59</b>
<b>C</b>	<b>Binary to Octal Conversions Performance</b>	<b>68</b>
<b>D</b>	<b>Binary to Hexadecimal Conversion Performance</b>	<b>77</b>
<b>E</b>	<b>2's Complement Questions Performance</b>	<b>86</b>
<b>F</b>	<b>Binary Arithmetic Performance</b>	<b>95</b>
<b>G</b>	<b>Floating Point Performance</b>	<b>104</b>
<b>H</b>	<b>Exam Performance</b>	<b>113</b>
H.1	Summer 2015 . . . . .	113
H.2	Fall 2015 . . . . .	114
H.2.1	First Exam . . . . .	114
H.2.2	Final Exam . . . . .	115
	<b>Bibliography</b>	<b>116</b>

# List of Figures

2.1	ClassCraft: An example of a gamification tool. . . . .	5
2.2	Flight Simulator: An example of game-based learning. . . . .	7
2.3	Alice: A game-based tool to learn programming. . . . .	8
3.1	Login screen . . . . .	15
3.2	Character controls . . . . .	16
3.3	Character status screen . . . . .	17
3.4	Quest log . . . . .	18
3.5	Battle system . . . . .	19
3.6	Battle results screen . . . . .	21
3.7	Town map . . . . .	22
3.8	Map of forest level . . . . .	24
3.9	The reaper boss for the homework quest line . . . . .	26
3.10	Website profile page . . . . .	29
3.11	News and updates page . . . . .	31
5.1	Survey answers . . . . .	36
5.2	Students that played the game (Summer 2015) . . . . .	38
5.3	Student's that did not play the game (Summer 2015) . . . . .	39
5.4	Comparison graph between students that played and those that did not play (Summer 2015) . . . . .	40

5.5	Comparison between students that played and students that did not play in First Exam (Fall 2015) . . . . .	42
5.6	Comparison between all groups of students for the Final Exam (Fall 2015) . . . . .	44

# List of Tables

A.1	User details showing game completion and number of questions answered. . . . .	50
B.1	User's performance in-game for decimal to binary conversion questions.	59
C.1	User's performance in-game for binary to octal conversion questions. .	68
D.1	User's performance in-game for binary to hexadecimal conversion questions. . . . .	77
E.1	User's performance in-game for 2's complement questions. . . . .	86
F.1	User's performance in-game for binary arithmetic questions. . . . .	95
G.1	User's performance in-game for floating point questions. . . . .	104
H.1	Percentage of students with correct answers in exam 1 and exam 2 (Summer 2015). . . . .	114
H.2	Percentage of students with correct answers in first exam (Fall 2015).	115
H.3	Percentage of students with correct answers in final exam (Fall 2015).	115

# Chapter 1

## Introduction

### 1.1 Problem Statement

With rapid advances in gaming technologies during the past several decades, and with most of the current students belonging to the millennial generation [10], it is understandable that most, if not all, college students use games either as a recreation tool or as a more serious pastime. Thus, traditional tools and methods of review course materials may feel inadequate, outdated and boring to current students. It is important to leverage these observations into the current education system in order to motivate and recapture students' interest in the subject. Game based learning tools have found to be effective in motivating students to practice and review the subject at hand. Gamification, alternatively, gives students small goals to work towards, and is effective in keeping students engaged longer [7].



While both game-based learning and gamification are useful for certain applications [1][2][9], it is not clear whether they can be effectively combined for education applications. Could the usefulness of both be maximized if combined into a single holistic tool for education applications? What is the design trade-off between game-based learning and gamification for such applications? Using these questions as a starting point, the different aspects of gamification and game-based learning were explored and a tool combining both was developed in order to examine its benefits in an actual college setting.

## 1.2 Contribution

The main contributions of this thesis is three-fold. First, the similarities and differences of gamification and game-based tools are explored, and a system that integrates both into one complete tool is proposed.

Second, a tool based on the proposed system is developed that can be used in the Computer Organization and Programming course offered by the Computer Science Department for the undergraduate curriculum. The tool developed is not intended to replace traditional teaching methods, but rather used alongside them.

Third, the tool is released during 2 semesters in order to see how it is used by students. Their performance in the class after playing the game was maintained, and their feedback on the tool was obtained, to see how the tool as a whole can be improved.

## 1.3 Outline

This thesis is organized according the following outline. In Chapter 2, the topics of gamification and game-based approaches from the stand point of education are reviewed. Examples and literature available on these two ideas are looked at. The development of my tool, Academia Arcana, is described, explaining the requirements, choices, and final ideas of development. In Chapter 3, all aspects of the game, as well as its website back-end are covered. The overall design behind the game in its entirety is explored. In Chapter 4, the design of the research study and its methodologies are discussed. The choice of metrics to determine the sucess of the tool is explained. In Chapter 5, the game's reception by the students and their use of it is explored. Their performance both before and after the game is taken into account and compared with the students that did not choose to play the game. Finally, in the final chapter, my conclusions are noted and the tool's expansion, future work and its current limitations are discussed.

# Chapter 2

## Background

### 2.1 Gamification

Gamification refers to the incorporation of game like elements and principals into non-game contexts [4]. Using gamification, ordinary and repetitive tasks can be converted into a game, creating incentive to complete the tasks. Gamification has seen growth in many fields, with the advent of many companies that deal exclusively with the integration of gamification into various fields [8].

However, although gamification started to gain popularity in recent years, it is not a new concept. Primitive forms of gamification can be seen in our day to day lives. Supermarkets and grocery stores often allow shoppers to gain points during their regular shopping trips. Airlines and hotels offer loyalty programs to travelers who regularly use their services. Even parents gamify chores by rewarding their

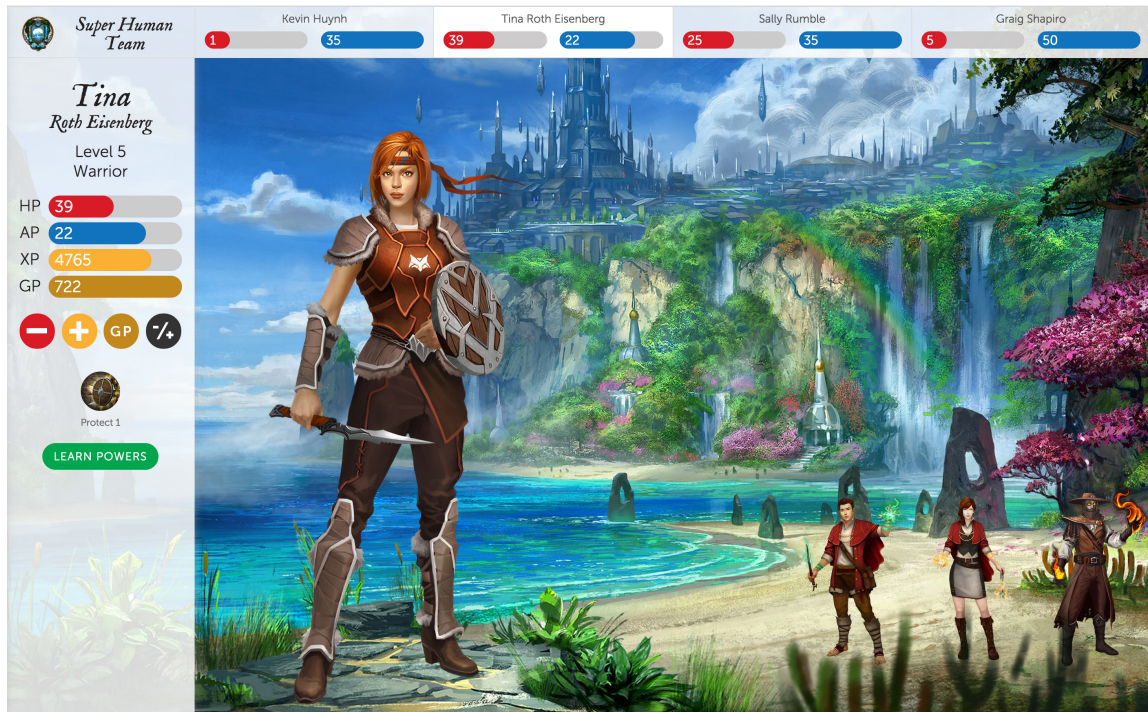


Figure 2.1: ClassCraft: An example of a gamification tool.

completion with an allowance.

In the field of academics, many examples of gamification covering the many different facets of education [3] exist. Gamification of course material can be seen in tools such as KnowRe (personalized math learning) and DuoLingo (language translations). Tools such as ClassDojo and ClassCraft gamify classroom interactions. Coursera partners with many Universities to provide online versions of their courses in a gamified manner.

Primarily, gamification consists of some combination of 3 major features that are listed below.

### **2.1.1 Points**

In order to be successful, gamification tools need to provide their users with a way to measure themselves. Points are earned each time a user does something that is useful. Assigning a points system makes users try to raise their scores as much as they can.

### **2.1.2 Rewards**

Rewards are given to users who complete a significant task or make a significant achievement in the tool. Rewards give the users goals to work toward, and work as small incentives.

### **2.1.3 Competition**

In order to have a healthy user growth in a game with multiple users, there must be some level of competition. Thus, gamification in learning tries to bring that same growth to the education field. Competition does not have to directly pit users against each other, in fact, a majority of gamification tools provide healthy competition in the form of leaderboards. Having a ranking system is a good way of increasing interest in using the tool.



Figure 2.2: Flight Simulator: An example of game-based learning.

## 2.2 Game-Based Learning

Game-based learning is the use of games as part of the instruction. Game-based learning is designed to support the course material with gameplay, in a risk-free game environment. In game-based learning, users are drawn into a game environment, where playing the game is synonymous to learning. In addition to this, games and game-based learning let users concentrate on the game's goal, because if a player does something wrong in a game, it will not have an impact in the real world. Users can forget about their insecurities and inhibitions about making mistakes and instead concentrate on winning the game. Simulators such as Flight Simulator and America's Army are examples of games which can simulate real-life experiences, and allow users to practice without the worry of making mistakes.

Game-based learning applications primarily succeed because of their method of presenting data. Traditional teaching methods fail to engage the current generation of students, who are more used to interactive media. Game-based learning allows

for the repetition of what a student needs to study, but through the use of a game, allowing them to spend more time with the game than traditional reviewing methods.

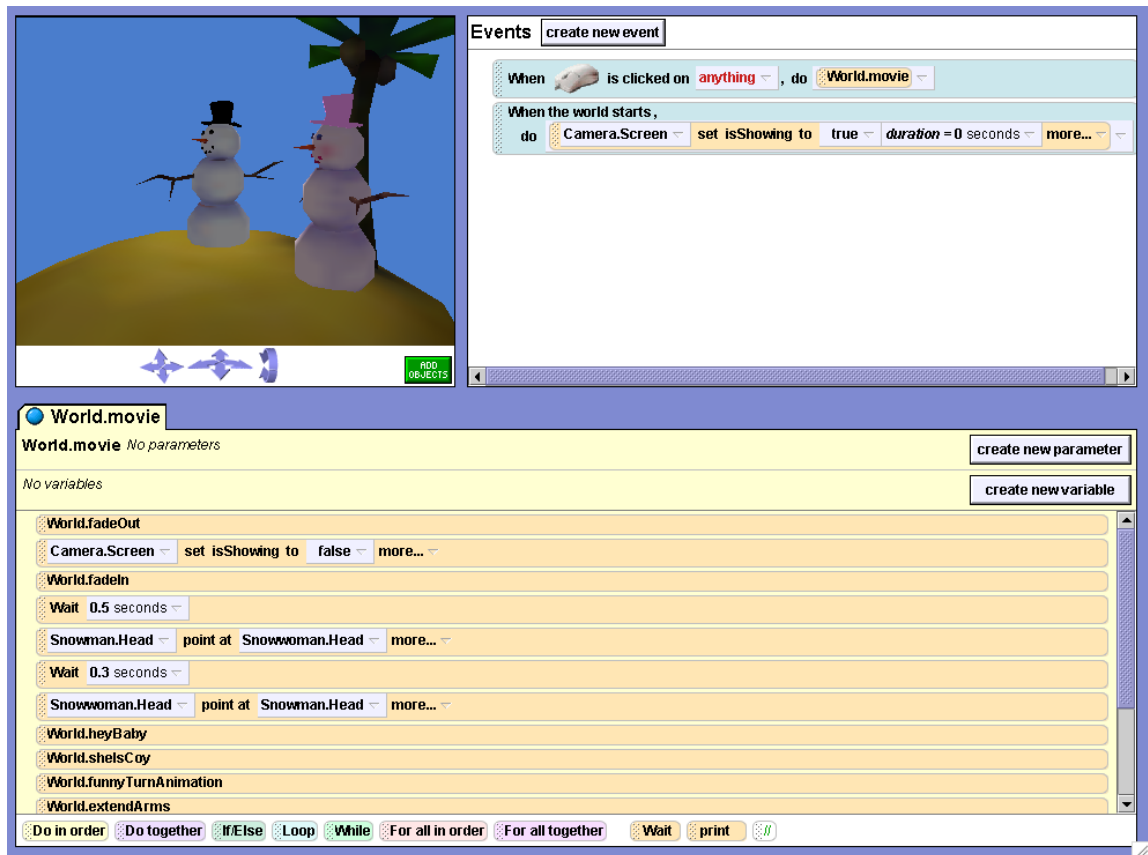


Figure 2.3: Alice: A game-based tool to learn programming.

## 2.3 Gamification in a Game-Based Environment

The major consideration that was made during the design of the game was the trade off between the presentation and repetition of the class material and the leisure of playing a game. I realized that the game should not digress too far from its main

goal of providing an additional tool for review, but at the same time, it should be fun and interesting enough to engage the users and make them want to play more.

A way to gamify the class was required, that still preserved the gamified aspect while presenting it to the user in the form of a game. Traditionally, game-based learning focuses on one particular topic and a game is created that can be used to help learn that particular topic. A "base game" was required that could be continuously altered during the entire process, and was adaptable enough to cover multiple topics while still giving the feel of a holistic game. Taking all things into consideration, I felt the best way to do this was to develop the tool in the form of an RPG game. Players would interact with the tool like any traditional RPG game. All classic RPG elements, such as a basic character customization, level, stats and rewards, would be present, and would correspond to how well-versed a student was when it came to the class. At the same time, all material and questions would be presented in the form of a game.

I felt this genre would work best for the game since I could both gamify the course material and create a game that students could play in the same tool. Role-playing games inherently have many of the major features that gamification borrows from. Points (experience points and level), rewards (loot), badges (achievements), ect. are all present in almost all RPGs. At the same time, since RPGs are so diverse, a game-based learning tool could easily be integrated as part of the tool.

Role-Playing Games primarily have three major and distinct game-play features that attract players, character development, exploration, and combat. Traditionally, these games are set up in a way that players can design their own characters, use



their character to explore the world, and often times find themselves having to fight amongst the enemies of that world. As it was believed more enthusiasm would be shown by the students to use the tool if the course material was introduced as a part of the game instead of the taking over the game completely, the course material was integrated into the combat part of the game. The gamification aspect was driven by the character development part. The exploration part of the game would not be affected much, but small references to the class were added into the game world.

## **2.4 Development**

After deciding on an RPG genre, planning the development of the game was the next step. The platform on which the game would be launched was the first thing that needed to be decided upon.

### **2.4.1 Platform**

After careful consideration, Unity3D was chosen as the game engine the tool would be built on. Unity3D is a very flexible platform for building games and is also very user-friendly. I believed a good game could be created within a short amount of time using Unity, based on their tutorials and forums.

Since 3D was already supported by Unity3D, a solid foundation on which to build the game upon was present.

### **2.4.2 Setting**

After the platform was chosen, a setting for the game needed to be decided on. A fantasy setting was chosen because of the possibility to creatively include many different features into the game.

### **2.4.3 Gamification of Course**

In order to incorporate the gamification of the course into the tool, the part of the course that could be gamified needed to be chosen. The first part of the course was selected, because a good understanding of the best way to proceed in the future could be obtained.

In the first step of gamifying the course, the material was split into different sub-sections. The sub-sections were further divided it into a basic structure based on the order the topics needed to be covered. An expected character level was assigned to each subsection. This level is what the player is expected to have reached when they start review on that particular topic. Thus a learning curve was obtained against which the game was balanced.

Next, the quests were planned out, which required players to answer questions based on each topic. Each topic was covered by at least one quest, and the player was rewarded when the quests were completed with a unique reward, such as extra interactions with the NPCs (non playable characters) and loot. Special quests were then created, such as a tutorial quest and a quest that rewards players with a

homework grade.

Lastly, a ranking system for the players of the game was created based on how much they used the game and how well they did. This ranking system was designed in a way that everyone should be able to achieve first place no matter when they started using the tool, as long as they are able to understand the material.

#### **2.4.4 Game-Based review**

Once the basics of the gamification of the course were created, repetition was decided as the best way to review the material. Thus the combat mechanics of traditional turn-based RPGs were modified to suit the needs of the review tool. In turn-based combat, an action is selected by the player during their turn. Once the player's turn ends, an action is chosen and performed by the enemy. The new mechanics involved a new action added to the player's turn. Whenever an action is selected by the player, a question was asked which required an answer. Multiple chances to answer the question were provided, and players had access to hints, but the questions were timed to help improve both speed and accuracy. Since combat was a major part of the game, students playing the game should have got adequate review. The questions asked were based on a random generation of questions for each topic.

Since the questions and answers were generated randomly, students had an unending amount of questions to answer, and instant feedback could be provided for their answers without having to wait for the TA or professor to grade their work.

## Chapter 3

### Academia Arcana

The name of the tool was chosen to be Academia Arcana. The game was an RPG (Role-Playing Game), combined with a turn-based action system, where users could create a character that represents them in the game world. A fantasy medieval setting was chosen for the game as it was felt it allowed for a lot of creativity.

The requirements for the game were: that it should be challenging enough that students would feel like they accomplished something non-trivial when they finished; that it should present only information that is directly related to the specific goal at hand; and that it should help students understand and solve problems in the course faster [6].

## **3.1 Game Goal**

The main goal of the game was to assist a town that is plagued by monsters. As a player progressed through the game, he or she would have encountered monsters of increasing difficulty, and gained rewards and reviewed class material along the way. The main idea is that upon completion of the game, students would be able to answer any questions they would encounter in the class exams.

## **3.2 Gameplay**

The various gameplay features and design elements of the game are discussed below.

### **3.2.1 Accessing the Game**

Students who had decided to participate in the game were given access to a link that allowed them to download the tool. In addition, they were provided with credentials that allowed them access to the tool. Upon starting the tool, users will be greeted with a log-in screen. Using the credentials provided to them, they will be able to log in and use the tool.

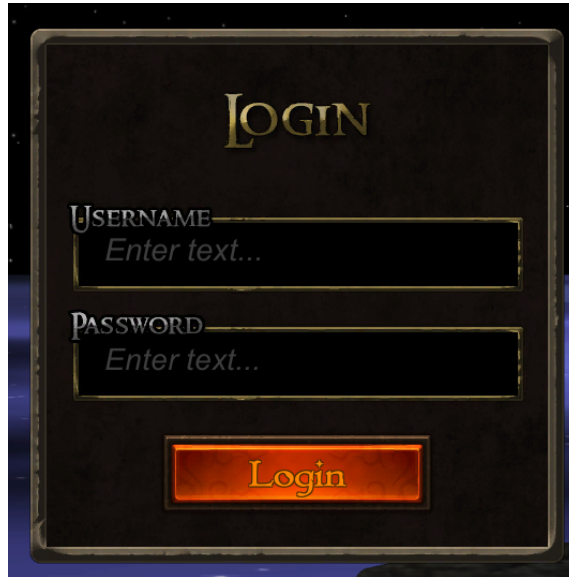


Figure 3.1: The Login Screen. The portal students use to access the game.

### 3.2.2 Character Creation

Once a user has logged in, they will be asked to create a character. Here they will be allowed to enter a name for their character, as well as to choose the gender. For the initial version of the game, these are the only customization options available.

### 3.2.3 Controls

Controls in the game are similar to many traditional 3rd person RPG games. A mouse is recommended, but not absolutely required.

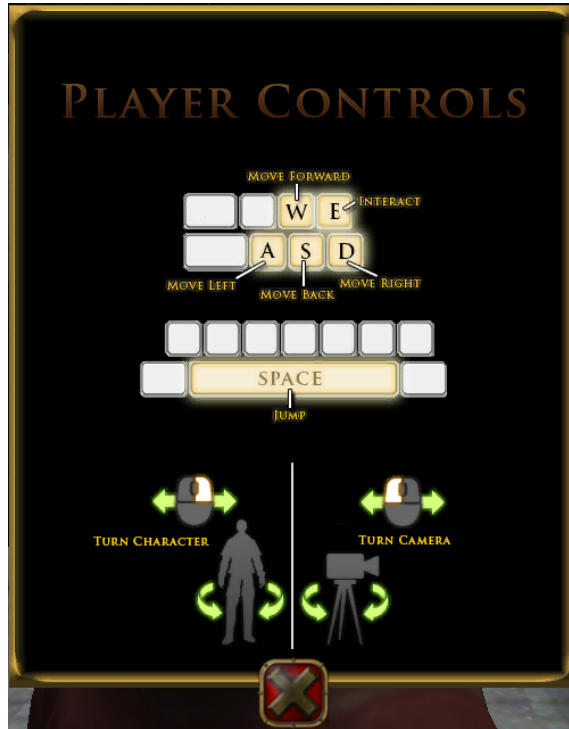


Figure 3.2: The controls used to move a character around in the world and interact with NPCs

In addition, a character will have access to an 'interact' button, which will allow them to interact with the various non-playable characters that populate the world.

### 3.2.4 Character Screen

The character screen allows a player to see their level, stats, and current wielded weapon. As a player levels up, their stats are automatically updated. Although this restricts the customization aspect, it allows for more control and balance between the player and the enemies.



Figure 3.3: Character status screen, showing player level, stats and gear.

#### 3.2.4.1 Level

As a character progresses through the game, fighting monsters and finishing quests, his level will rise to a maximum of 10. Each level up will increase his stats and will correspond to the player's completion of a certain topic in the game. Many parts of the game are tied into the player's level, and as a player raises their level, they will find that the difficulty of the review questions also increases. This way, the difficulty of the game changes only when the player is ready for the change. A student that reaches the maximum level would have answered atleast 75 questions relating to topics covered in the course, all of varying difficulty, and should be ready



to answer similar questions in the exam. The level system is an important part of the gamification of the class.

### 3.2.5 Quests

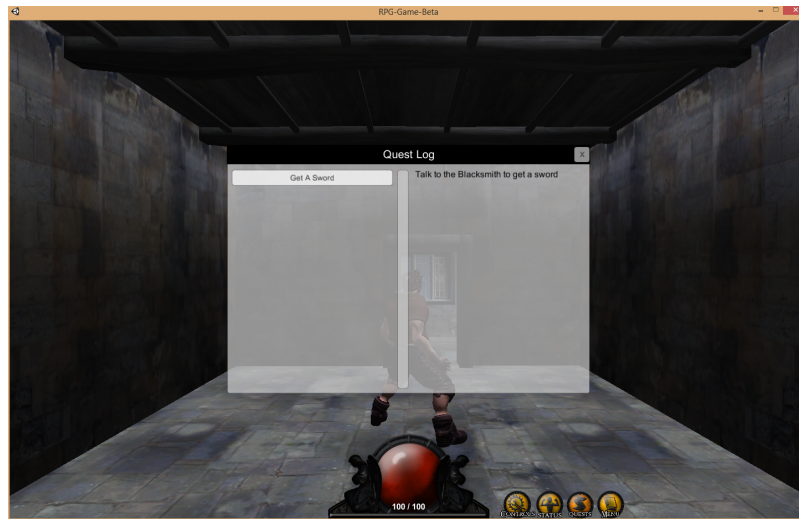


Figure 3.4: Screenshot of the game showing the quest log.

Quests are small tasks players can do to progress through the game. Quests get unlocked for each player at certain points in the game, depending on the player's level. Completion of a quest awards a player with some small in-game reward, such as unlocking new areas, or gaining new weapons. Quests also help guide the players through the game, and hence, should be completed as soon as they become available. The quest system is one of the major aspects that allows for the gamification of the course.

### 3.2.6 Battles

Battles in the game are triggered by interacting with enemies. This leads to a new location, where the player and enemies take turns to attacking each other. Enemies damage the player automatically, but players must answer a question successfully in order to do damage during their turn. The damage a player deals to their enemy is dependent on many factors, but the most important factor is the Attack Damage Percentage (ADP).

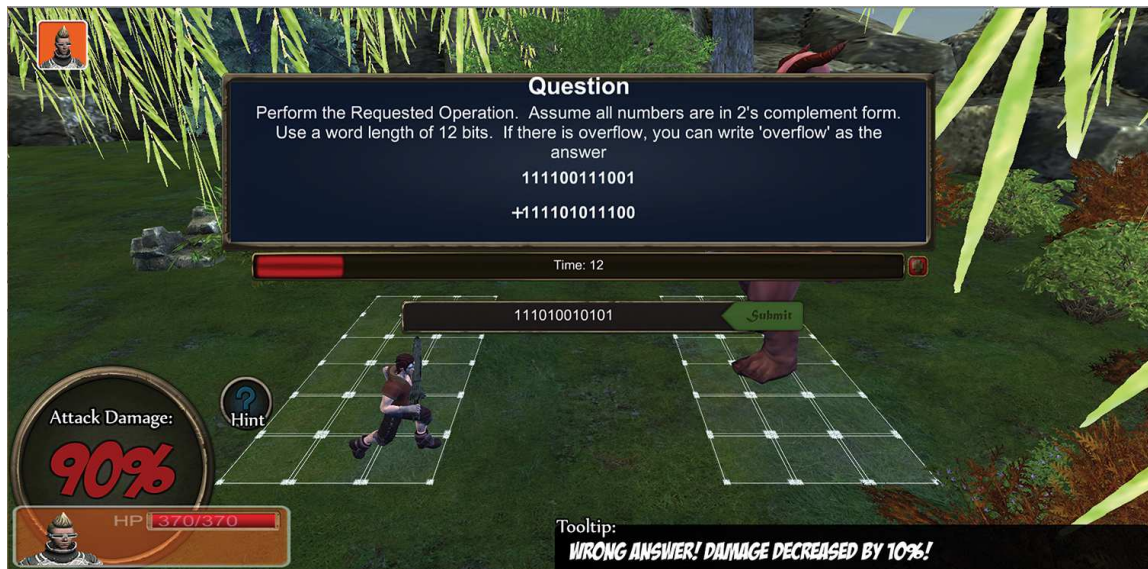


Figure 3.5: A Screen Shot of the battle system, showing an example of a question a player will be asked during their turn.

After the player selects an attack and target, they will be provided with a question to solve. The type of questions asked varies with the enemy selected. Incorrect answers will result in a 10% reduction in your ADP. Failure to answer within the

given time will also reduce the ADP, but some extra time will be added. The number of times extra time can be added will vary between questions, but will definitely be between 2-3 times. If the player is stuck, they can also access a hint which will tell them how to work out the problem. Using the hint will also reduce the ADP. The player's turn will end when one of the following three events occurs:

1. The player provides the correct answer.
2. The player runs out of time and any extra time available.
3. The ADP drops to 0.

In the second and third case, the player's turn will end with them dealing 0 damage to the enemy. However, in the first case, the ADP is multiplied into the damage calculation roll in order to determine the final damage. Thus, students are encouraged to try to solve the question quickly, but with minimum errors.

#### **3.2.6.1 Results**

At the end of every battle, players will be able to see the in-game rewards that they earned. Each battle awards a player with Game Score, Gold and Experience. Gold can be used at the healer in exchange for healing services, while Experience is used to level up the player.



Figure 3.6: Battle results screen, showing question type, time taken, number of attempts, and if the question was answered correctly.

Players will also be able to see the individual information about the questions answered. This information includes what type of question it was, if the player was able to answer the question, how long the player took, how many attempts the player had, if they needed to use the hint, as well as the answer the player provided, compared with the expected answer. This process of instantaneous feedback ensures that players understand how and why they answered a question incorrectly, and also provides them some analysis into their procedure of answering the different types of questions.

### 3.2.7 NPCs

Throughout the game, the player will be expected to interact with NPCs in the town level. A list of the NPCs and how they progress the story is given below.

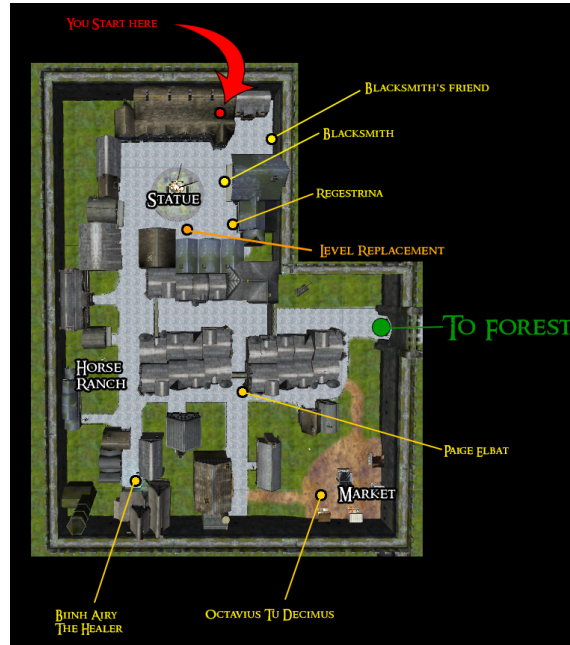


Figure 3.7: Town Map showing player's starting location, explorable area, and location of key NPCs.

#### 3.2.7.1 The Blacksmith

The blacksmith is the first NPC players will interact with. He will also start players off by assigning them the Tutorial Quest and awards them with the starting sword

#### **3.2.7.2 Bii'nh Airy The Healer**

Bii'nh Airy is the healer for the town, who provides healing services to the player during their time in the game.

#### **3.2.7.3 Paige Elbat**

Paige Elbat is the Mercenary Guild Translator. She has a new and powerful sword for the player, but they need to prove themselves first!

#### **3.2.7.4 Octavius Tu Decimus**

Octavius is a knight who lost his friend to the attacking monsters. If the player kills enough of the monsters to appease him, he will reward the player with a powerful artifact.

#### **3.2.7.5 Registrina**

Registrina gives the player the final quest. Once the player has helped everyone else in town, Registrina will give the player the most powerful weapon in the game.

### **3.2.8 Enemies**

Enemies in Academia Arcana are encountered in the Forest Level. Each enemy has its own stats and requires an understanding of a different concept to defeat.

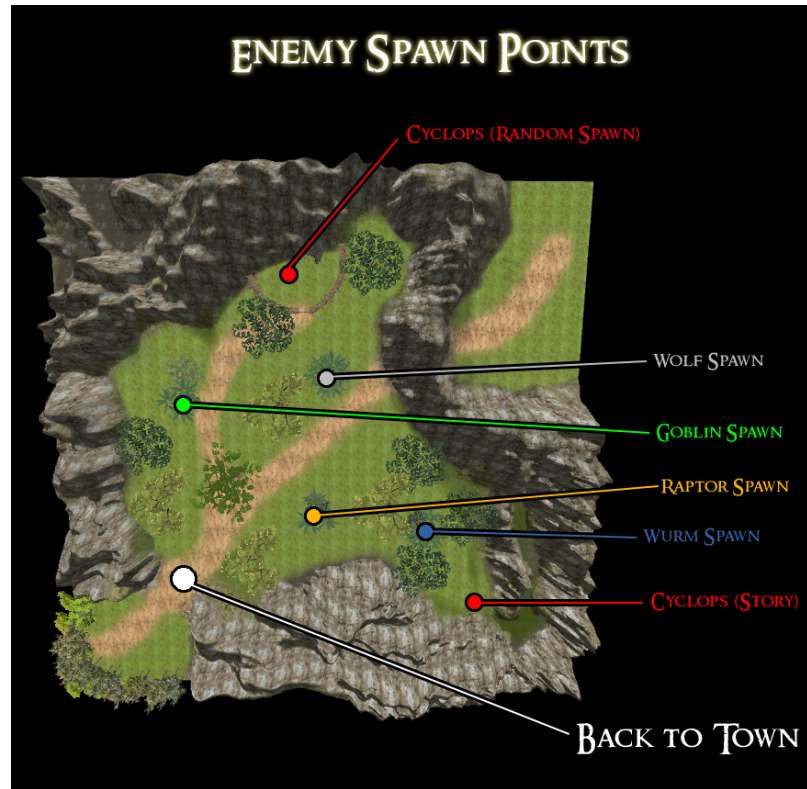


Figure 3.8: The map of the forest level, showing where the monsters will spawn and the explorable area.

### 3.2.8.1 Goblins

Goblins are the first tier of enemies the player will face. Goblins are weak, but large in number. In order to defeat the goblins, the player will need to answer questions on basic conversions between number systems. After a certain level, the goblins will be replaced with a stronger counterpart that will have harder questions on the same topic.

#### **3.2.8.2 Wolf**

The wolf is an enemy that appears for the player once they hit level 4 and unlock the required quest. Wolves can only be defeated by a player that can answer questions on Binary Arithmetic as well as 2's Complement. As with the goblins, the difficulty of the questions asked will rise with the player's level.

#### **3.2.8.3 Raptors**

Raptors are large dinosaurs that only appear once the player reaches level 6 and unlocks the quest. Raptors will prove to be a challenge to players that are unable to answer questions on IEEE Floating Point standard. As with the other enemies, the difficulty scales with the player level.

#### **3.2.8.4 Wurms**

Wurms are large insect-like beasts that roam the forest only when the player has reached a level of 8. Any question from any of the other monsters can be asked while the player is dealing with the wurms, and often they are more difficult questions.

### **3.2.9 Bosses**

Bosses in Academia Arcana are major obstacles that the player must overcome. Each Boss provides the player with an additional reward in addition to the regular in-game rewards.



### 3.2.9.1 The Reaper

The Reaper is a large skeletal boss that appears in the forest when the player first enters. The reaper is a challenging enemy, that requires an understanding of all the concepts covered by the game. If a player has a hard time fighting The Reaper, they can move on with the main story line and come back to finish him off.



Figure 3.9: The Reaper Boss that awards players a homework grade for completing the quest line.

When players defeat The Reaper, they get a free Homework grade in the class.

### **3.2.9.2 The Cyclops**

The Cyclops is the final boss of the game. In order for a player to defeat The Cyclops, they need to answer any type of question, at a difficulty comparable to what they will have on an in-class exam. Players can judge for themselves how they do using this as a basis.

## **3.3 Website**

In addition to the game, users also have access to a website that serves numerous functions. The website will essentially be a portal that players can use to keep track of the progress they have made through the game, to see an overall view of their personalized statistics of their gameplay, to view their ranking among the other students in the class, and to keep up with any news or updates that the instructor or teaching assistants announce in the course. The website is only accessible to the players, using personal logins corresponding to the same credentials that they use to access the game.

The website was designed to be fluid in layout, allowing for easy viewing on different types of devices (monitors, tablets, and phones). The main technologies used for the development of this website is HTML, CSS, and PHP, which allow it to be easy to update, modify, expand, and also allow an app to be developed out of it.

The website is divided into 3 main parts: the Player Profile, the Class Leaderboards, and the News and Updates Bulletin. Each part serves a role in the user's

overall experience.

### **3.3.1 Profile**

The main objective of the profile is to help students identify the areas or topics of the course that they are least comfortable with, and require more practices on. A radar chart is chosen to display the statistics to the students, because it is an ideal approach to display the performance metrics of a system [2]. In sports, radar charts are regularly used to form athlete profiles, and are used to show their strengths and weaknesses as well as to compare them with their peers. It was believed that when used in our website, it would case students to work harder and use the tool more, so as to improve their stats and have a better graph.

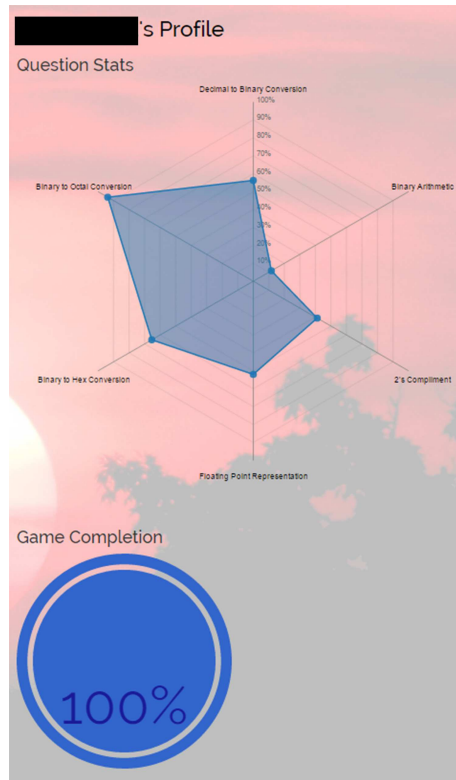


Figure 3.10: The Profile section of the website, showing a player's radar graph as well as their percentage completion of the game

The profile is also approached with a modular design, making it easy to add and implement any other plots or charts of the data, in order to expand the information provided to the students as feedback. All game-data is stored in a database back end, and can be displayed to the player in any desired form when requested.

### **3.3.2 Leaderboards**

The Leaderboards are another way to improve the level of gamification of the course. The leaderboard is primarily to provide a ranking to the players, so they can see where they stand with respect to the others in the class playing the game.

Initially, many different ideas and benchmarks to rank the users were considered, but finally a ranking based on the total number of questions answered correctly was chosen. The reason this particular ranking was chosen is that it provides a reasonable goal for the users to strive for [5]. The player's score can only continue to grow, as no negative aspect (ex. a player's inability to answer a question) is considered in the formation of this ranking. Thus any player can increase their position on the leaderboard by increasing their usage of the tool and working through more problems.

A player's details and statistics are private, and not shown to any other player, thus the ranking system only provides an indirect measure of how another user is doing.

### **3.3.3 News/Updates**

The News and Updates Section is primarily used as a liason between the instructor and Teaching Assistants of the course, and the students. Important course information is provided to the players. This section also shows vital in-game information, such as what rewards the player has unlocked.

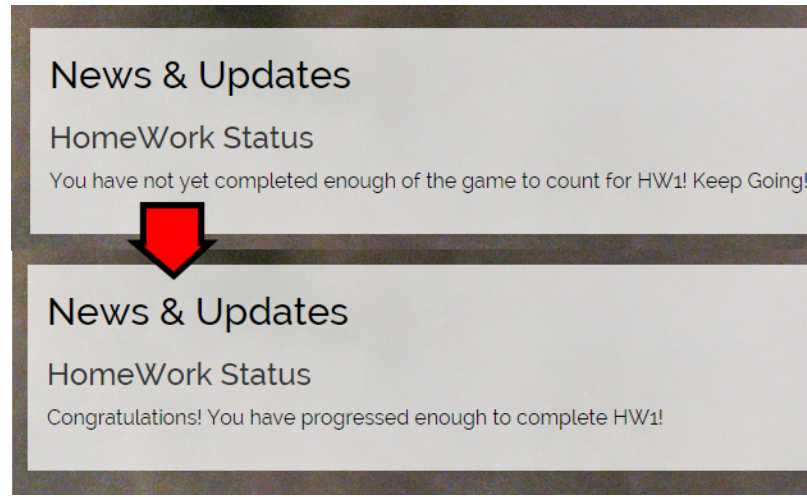


Figure 3.11: The news and updates showing an example of how the player is informed of any updates in the game.

### 3.4 Question Generation

Currently, the question generation system is a complete procedural generation system. This means that each question is created using an algorithm when required. This ensures that students have an unending supply of questions to answer. This is also helpful, as the solution to these questions can be automatically generated, thus it is possible to give a student instantaneous feedback on where he or she may be going wrong while answering the question.

There is also support for a fixed question generation system, which allows for the professor or TA to manually enter specific questions or a question bank they would like the students to review and the game will use those questions as well.

## Chapter 4

# Research and Methodologies

In order to ensure that the tool was helping students of the Computer Organization and Programming class, the game was released to the students during the Summer '15 semester and the Fall '15 semester.

There have been many studies already to demonstrate that gamification or game-based learning can be used effectively to improve a students performance. The main point of this thesis was to develop a tool combining both, and seeing how students used it, and if it helped them during a regular college semester. Real college students were the participants in the study, and there was no change in the way the course was taught. Apart from the consent form for their participation, it was ensured that students would not feel like they were a part of a study.

Thus, in order to use the tool in the classroom there were many conditions that were followed.

1. Participation in the game was completely voluntary. This ensured that everyone had an equal opportunity to decide, for themselves, if they did or did not like to play the game.

2. Those who chose not to play the game, did not receive any disadvantage or advantage over participants and vice versa. Playing the game did not yield any benefit apart from the repetition and review of material that the game provided.

3. The game was a tool that students used for review on their own time. No special circumstances were given to students to play the game during class time.

4. No participants were excluded from the study unless they specifically asked to be excluded.

5. Only students who were taking the course during the time period of the study were allowed to participate in the game.

Thus students were allowed to either choose to participate in the study or not, with no pressure to choose one over the other. It was found that while initially students were divided on if they wanted to play the game or not, many students started playing the game when they realized that they did require more practice to succeed in the course. Also, many students started because their friends had played it, and told them they should check it out.



## **4.1 Game Inspired Research Methods**

Over the course of the project, while working on gamifying the course and building a game-based environment, it was realized that game inspired features could be used in designing the overall study. These different game-inspired research methods are detailed below.

### **4.1.1 Creating a Community**

One of the major parts of the study that worked really well was that participants were allowed to feel like they were part of a community, instead of a subject in a study, while their individual anonymity was retained. Students were aware that the rest of the class had the choice to be a part of the study as well. This way they were allowed to discuss the project as a whole, but didnt have to disclose personal details unless they wanted to. This also allowed us to design a leaderboard, and introduce a little bit of competition to the game. The leader board ranked the students according to their progress in the game, thus everyone had a chance to climb higher, and provided some incentive to play the game.

### **4.1.2 Personalized Goals**

Another game-inspired method was personalized goals. The major goal was to get the participants to play the game. However, instead of presenting it as such, a small story line was created with small individual goals that progressed the same. This

way, the final goal was being met step by step, as the participants worked their way through the story.

### **4.1.3 Intuitive Controls**

A consideration to be made was the learning curve participants would have to go through to efficiently be a part of the study, especially since they would be required to play a game. Thus the style and controls were carefully chosen to be simple and intuitive. Our controls were simple, and based on a similar structure to current games in the market. There were not complex controls that required anything more than basic computer skills to succeed. A very brief tutorial was used as well to make sure participants were comfortable with the game.

# Chapter 5

## Results

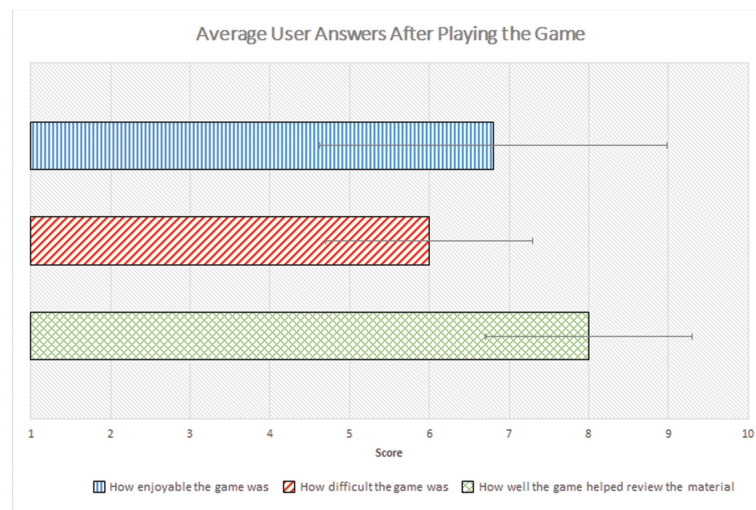


Figure 5.1: Survey answers

In order to determine the students views on the game, a short survey was taken upon the completion of the game. The results were positive. When asked how enjoyable the students found the game on a scale of 1-10, the average response was a 6.8. The

average response for the difficulty of the game, on a scale of 1–10, was 6. When asked how well they felt the game helped them review the relevant topics on a scale of 1-10, students replied with an average rating of 8.1. Most students also said they felt a sense of accomplishment upon finishing the game.

## **5.1 Summer 2015 Semester**

In the Summer 2015 semester, the students took the first exam without playing the game. After the exam, they were allowed to choose if they wanted to play the game or not. We then split the class into 2 parts, those that played the game, and those that did not, and compared their performance on the relevant questions before the game to their performance on the relevant questions after playing game. Since it was the summer semester, there were 28 students in the class, and none of them dropped during the semester. The results of both groups are shown in the following sections.

### 5.1.1 Students Who Played the Game

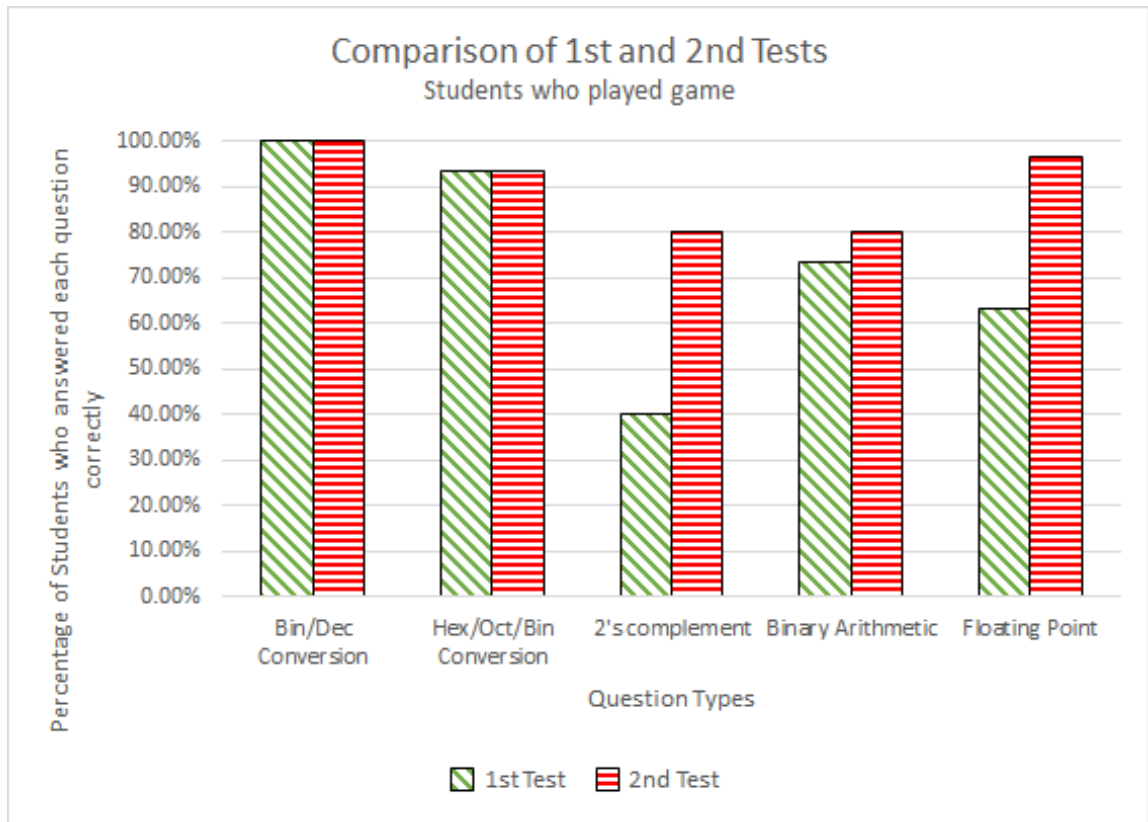


Figure 5.2: Percentage of students that played the game and answered each question correctly for both exams with the class average of the first exam

Students who chose to play the game already had a slightly higher average as a group than that of the entire class at the first test. After playing the game, the results showed that these students were able to achieve a higher percentage of correct answers in many of the topics covered by the game. In the other topics, these students scored at the same level as they did before playing the game.

### 5.1.2 Students Who Did Not Play the Game

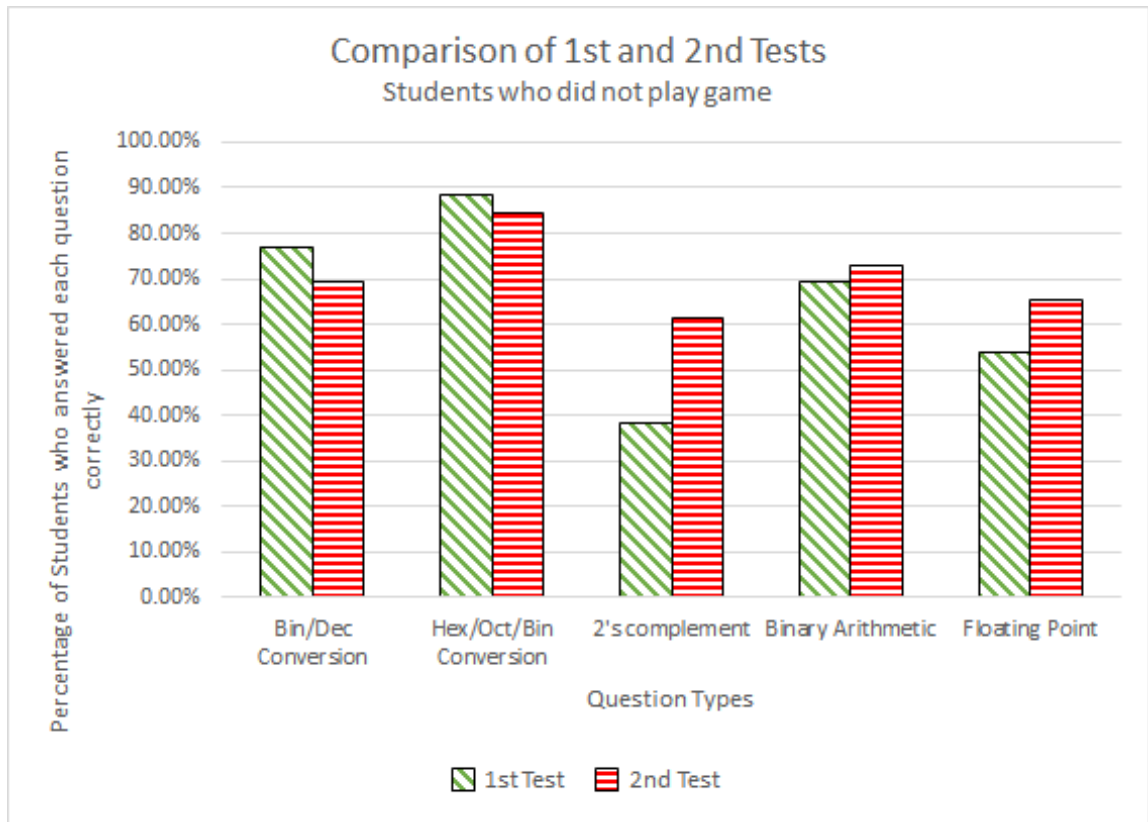


Figure 5.3: Percentage of students that didn't play the game and answered each question correctly for both exams with the class average of the first exam

The students who chose not to play the game already had a slightly lower number of correct answers than the class average at the first test. At the second test, the results of these students did not show the same improvement as the students who played the game. In fact, for many of the topics, students who did not play the game actually did worse at the second test than the first test.

### 5.1.3 Comparison Between Both Groups

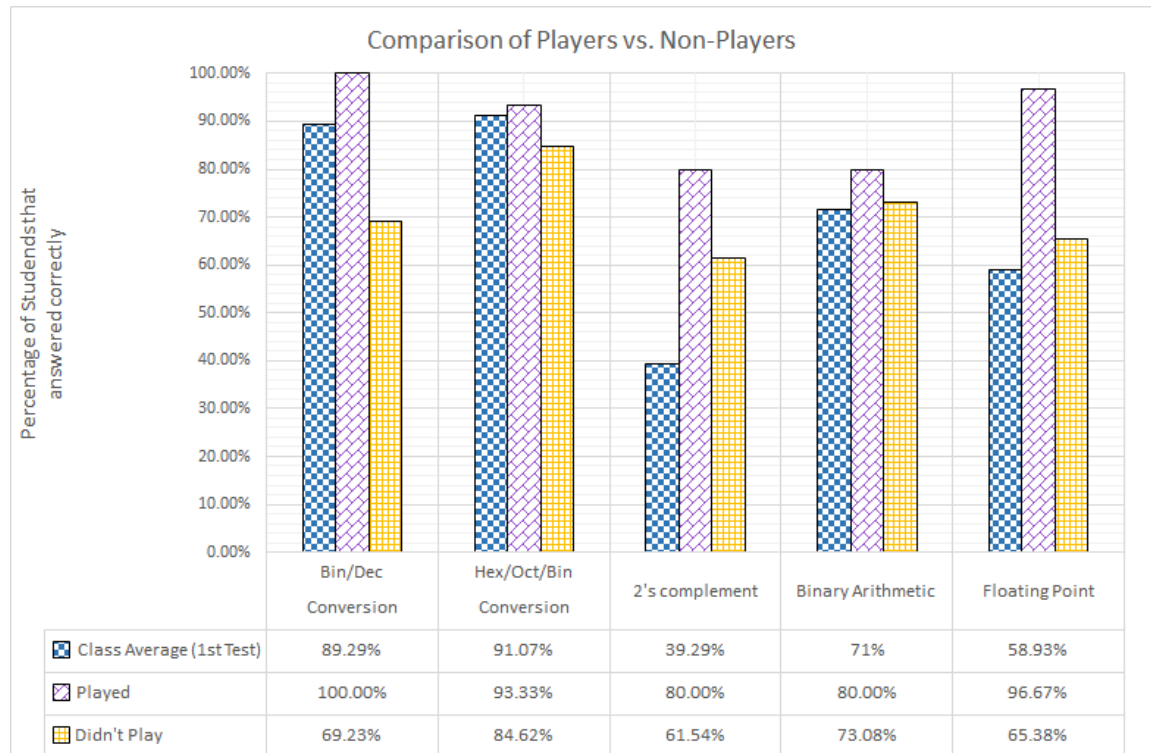


Figure 5.4: Graph showing the comparison between students who used the game and students who didn't play the game, compared against the class average from before the game

Comparing between the students who played the game and those who did not, it can be seen that for all question types covered by the game, the students who played the game did better than the students who chose not to use the game. In certain questions, a significant difference was seen between the two groups.

## **5.2 Fall 2015 Semester**

After the positive results during the Summer 2015 semester, it was decided that something different would be tried for the Fall 2015 semester. Similar to the previous semester, all students were allowed to volunteer to play the game, with no repercussions for those who chose not to play the game. However, those students who did choose to play the game had access to it from the beginning of the semester. We then checked if they were able to answer the pertinent questions on the first exam. The rest of the semester, students were allowed to continue playing the game, even though the game only covered the first part of the class. Some students stopped playing the game, some started late and continued to play the game through the end, and others did not play the game till the very end. Thus the class was split into 3 parts and checked their answers on the questions during the final exam, to check if continued use of the game would give students an advantage.

### **5.2.1 First Exam**

For the First Exam, out of the class of 140 students, there were 51 students who played the game, and the remaining 89 students did not. The results of both sections are shown in the following.



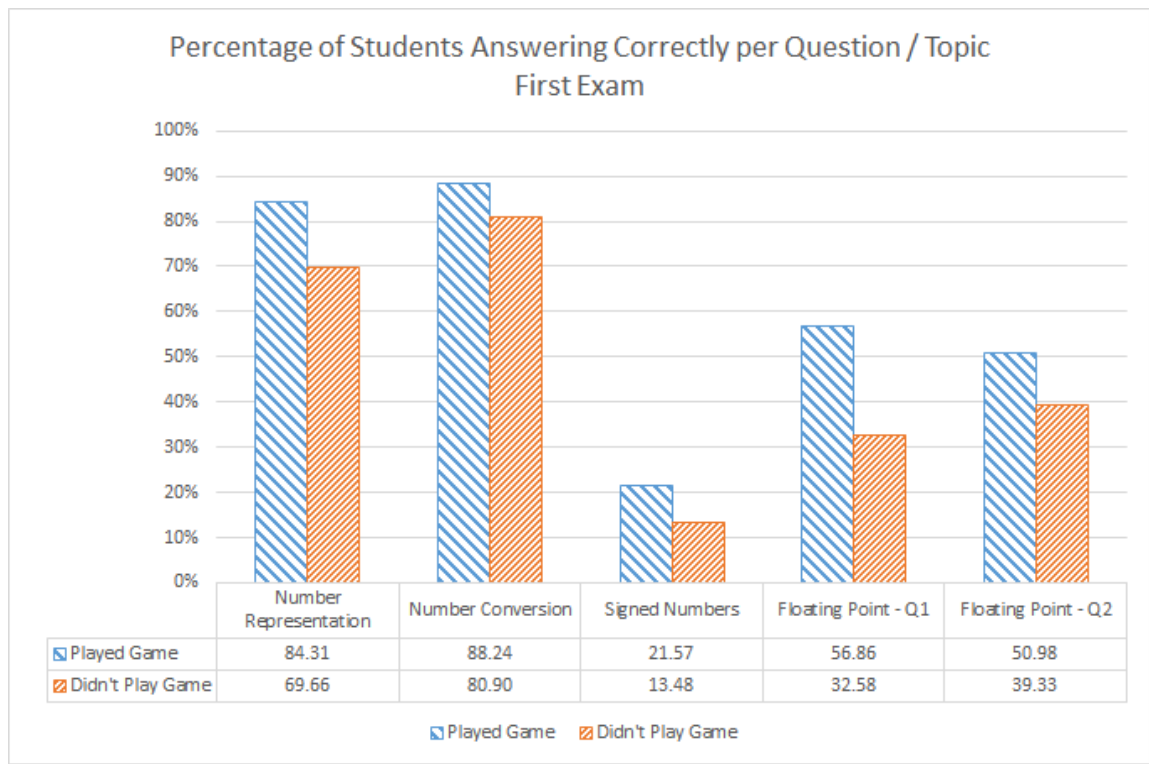


Figure 5.5: Graph showing the comparison between students who used the game and students who didn't play the game before the first exam in the Fall 2015 semester

Overall, the group of students who chose to play the game did slightly better than the other group. While a few of the topics were really close between the two, there were some sections where the difference was significantly larger.

This showed that the game was effective at helping students review, but helped with some topics more than others. Using this as a starting point, a future idea might be to improve the effectiveness by changing the way the review was presented for certain questions.

### 5.2.2 Final Exam

For the final exam, there were a few questions that were of a different type that what were usually asked in the review game. The remaining class of 124 students was split into three groups:

- **Students who consistently played the game.** These students either started the game since the beginning of the semester or after the first exam. They continued to remain active in the game throughout the semester till the final exam of the class, where the relevant topics were tested again. There were 52 students who consistently played the game.
- **Students who did not play the game.** These students chose not play the game at any point throughout the semester. The number of students in this group was small, with only 12 students, but their performance served as an important measure of the effectiveness of the tool.
- **Students who played the game inconsistently.** These students either stopped playing the game after playing during the first exam, or started late, but stopped playing soon after. There were 58 students in this group.

The performance of each of these groups is shown in the graph.

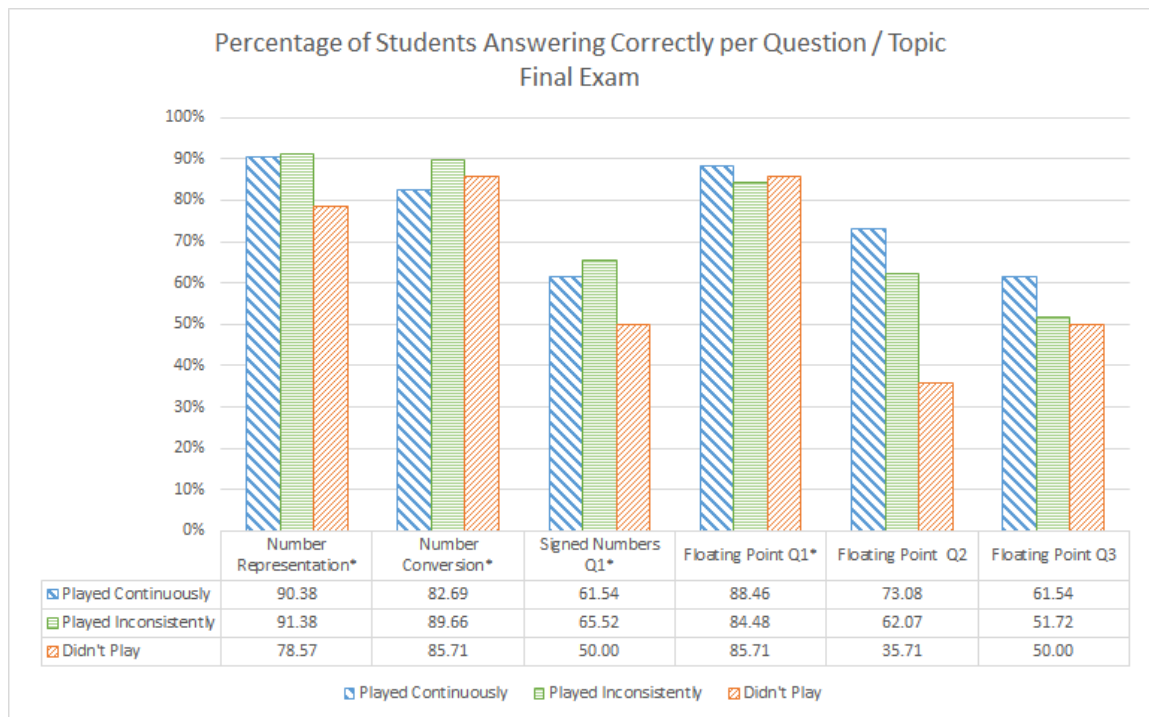


Figure 5.6: Graph showing the comparison between students who used the game continuously, students who played the game inconsistently, and students that did not play the game before the final exam in the Fall 2015 semester

Questions that were not similar to the gamified and game based review tool are marked with a star (\*). As it can be seen the results seemed to vary between the different topics and questions. Overall, on some of the questions that were not similar to the review game, students who did not play the game scored higher than those that did play the game, both consistently and inconsistently.

### 5.3 Discussion and Observations

There are many important points that can be seen in the data. For one, while the game did overall help the students who played it, when encountering questions they had not seen before, these students actually performed worse. This is something that needs to be updated, as the repetition of certain types of questions seemed to reduce a students adaptability to new and different questions. Secondly, the game seems to work really well with some topics, but not quite so well in others. This tells us that some of the topics need to be presented and reviewed in a slightly different way to maximize the potential of the tool. Lastly, students seemed to benefit the most when initially playing the game. For the most part, students who played the game inconsistently did similar to those that played the game consistently. This shows us that students seemed to retain the material easier when playing the game, and don't need to continuously repeat the review of the material over and over again.

Overall, the game was received positively by the students. Many students sent feedback thanking us for the opportunity to use the game, as they felt it helped them better prepare for the exams. All the students who played the game mentioned that using the website in conjunction with the game, really helped them identify the topics that they needed most review with. A few students mentioned that had they not had access to the website, where they could see their performance in the game, they would never have realized that they needed to review the material more. Students also said that with the quests in place, they always felt they had something to do in-game.

A game-based review tool seems to be an efficient way to help students review course materials. Instantaneous feedback on wrong answers allows students to check their work themselves, instead of having to rely on the instructor or teaching assistants. Gamifying the whole process by providing quests and level-locking them seemed to help increase interest in completing the game as well.

# Chapter 6

## Conclusion

Thus, two new and upcoming methodologies in the education field (Game based learning, and gamification) were able to be successfully combined into an efficient tool for review. While the design for the game was tailor-fitted for the class in question, the same procedure can be followed in order to work for other college courses. Based on the performance of the students who played the game, it is shown that our tool can help students review course material in a more effective manner than traditional methods.

### 6.1 Future Work

The game is in its preliminary stages, but can be expanded further later on. The game based review can be expanded to cover more topics of the courses, and the art can be further improved. Also, certain other dynamics can be added to the game

in order to make it more immersive and enjoyable. The game can be updated to include a wardrobe system, so students can change their characters clothing however they wish to. A pet system can also be introduced, having small pets that can follow the character around for aesthetic value or functionality like helping defeat monsters. Another expansion that is planned is a networked multi-player mode, in which students can team up with their classmates in order to defeat monsters that are much stronger than normal. This will allow students to improve their learning by collaborating with their peers towards a common goal. The website can also be improved to give more statistical data to the student to help them identify areas that they have problems with. Mini-games can also be created that can run in the background during class to give in-game rewards to students who are active in the lectures and participate in discussions.

# Appendices



# Appendix A

## User Details

Table A.1: User details showing game completion and number of questions answered.

UserID	Semester	Gender	Age	Game Score	Correct	Questions
1	Admin	Male	24	110	6	6
2	Admin	Male	24	10	170	176
3	Summer '15	Unsaid	Unsaid	0	0	0
4	Summer '15	Unsaid	Unsaid	1931	91	99
5	Summer '15	Male	20	1179	63	74
6	Summer '15	Male	20	30	12	13
7	Summer '15	Male	20	1351	91	121
8	Summer '15	Unsaid	Unsaid	0	0	0
9	Summer '15	Male	25	46	12	16

10	Summer '15	Male	20	2040	182	207
11	Summer '15	Male	22	1161	90	118
12	Summer '15	Male	18	1023	108	126
13	Summer '15	Unsaid	Unsaid	10	0	0
14	Summer '15	Male	21	44	11	12
15	Summer '15	Male	25	1504	76	89
16	Summer '15	Unsaid	Unsaid	81	21	24
17	Summer '15	Male	23	1503	89	91
18	Summer '15	Male	19	41	39	44
19	Summer '15	Unsaid	Unsaid	30	11	12
20	Summer '15	Female	22	1499	96	107
21	Summer '15	Male	22	1636	106	127
22	Summer '15	Male	24	811	59	76
23	Summer '15	Male	19	2169	118	141
24	Summer '15	Unsaid	Unsaid	0	0	0
25	Summer '15	Male	25	1776	176	196
26	Summer '15	Unsaid	Unsaid	263	34	49
27	Summer '15	Unsaid	Unsaid	0	0	0
28	Summer '15	Unsaid	Unsaid	32	9	10
29	Summer '15	Male	49	0	0	0
30	Summer '15	Unsaid	Unsaid	63	21	48
31	Fall '15	Unsaid	Unsaid	525	38	71
32	Fall '15	Unsaid	Unsaid	110	29	48

33	Fall '15	Unsaid	Unsaid	0	0	0
34	Fall '15	Male	20	430	32	43
35	Fall '15	Male	21	10	0	0
36	Fall '15	Male	20	110	26	40
37	Fall '15	Unsaid	Unsaid	0	0	0
38	Fall '15	Unsaid	Unsaid	0	0	0
39	Fall '15	Male	30	1281	82	96
40	Fall '15	Unsaid	Unsaid	125	23	47
41	Fall '15	Unsaid	Unsaid	140	22	38
42	Fall '15	Male	25	110	16	22
43	Fall '15	Unsaid	Unsaid	10	6	21
44	Fall '15	Male	26	220	77	130
45	Fall '15	Unsaid	Unsaid	10	0	0
46	Fall '15	Unsaid	Unsaid	110	47	60
47	Fall '15	Unsaid	Unsaid	10	17	18
48	Fall '15	Unsaid	Unsaid	190	29	42
49	Fall '15	Unsaid	Unsaid	110	17	24
50	Fall '15	Unsaid	Unsaid	300	120	180
51	Fall '15	Unsaid	Unsaid	1025	67	101
52	Fall '15	Male	19	165	29	46
53	Fall '15	Unsaid	Unsaid	0	0	0
54	Fall '15	Male	22	190	31	42
55	Fall '15	Unsaid	Unsaid	346	58	70

56	Fall '15	Male	21	110	50	80
57	Fall '15	Male	19	0	0	0
58	Fall '15	Male	21	110	16	18
59	Fall '15	Male	19	0	0	0
60	Fall '15	Unsaid	Unsaid	165	19	41
61	Fall '15	Male	21	130	15	15
62	Fall '15	Unsaid	Unsaid	140	20	48
63	Fall '15	Male	21	170	21	33
64	Fall '15	Unsaid	Unsaid	330	121	133
65	Fall '15	Female	29	110	32	41
66	Fall '15	Unsaid	Unsaid	325	39	51
67	Fall '15	Unsaid	Unsaid	110	25	40
68	Fall '15	Male	20	694	68	86
69	Fall '15	Unsaid	Unsaid	10	0	0
70	Fall '15	Male	22	110	16	19
71	Fall '15	Unsaid	Unsaid	1355	181	222
72	Fall '15	Unsaid	Unsaid	0	0	0
73	Fall '15	Unsaid	Unsaid	0	0	0
74	Fall '15	Unsaid	Unsaid	120	18	25
75	Fall '15	Unsaid	Unsaid	0	0	0
76	Fall '15	Unsaid	Unsaid	0	0	0
77	Fall '15	Unsaid	Unsaid	110	26	31
78	Fall '15	Unsaid	Unsaid	10	51	78

79	Fall '15	Unsaid	Unsaid	315	27	30
80	Fall '15	Male	23	165	31	40
81	Fall '15	Unsaid	Unsaid	10	0	0
82	Fall '15	Unsaid	Unsaid	378	53	70
83	Fall '15	Unsaid	Unsaid	0	0	0
84	Fall '15	Unsaid	Unsaid	110	18	22
85	Fall '15	Unsaid	Unsaid	165	19	39
86	Fall '15	Male	18	110	30	43
87	Fall '15	Unsaid	Unsaid	110	17	18
88	Fall '15	Unsaid	Unsaid	0	0	0
89	Fall '15	Unsaid	Unsaid	125	22	23
90	Fall '15	Unsaid	Unsaid	110	16	22
91	Fall '15	Unsaid	Unsaid	341	29	33
92	Fall '15	Unsaid	Unsaid	125	19	25
93	Fall '15	Male	20	635	89	127
94	Fall '15	Male	21	165	34	39
95	Fall '15	Unsaid	Unsaid	0	0	0
96	Fall '15	Female	19	540	41	63
97	Fall '15	Male	19	110	17	20
98	Fall '15	Male	19	1145	77	92
99	Fall '15	Unsaid	Unsaid	0	0	0
100	Fall '15	Unsaid	Unsaid	120	16	16
101	Fall '15	Male	20	10	114	157

102	Fall '15	Male	20	1890	111	123
103	Fall '15	Unsaid	Unsaid	0	0	0
104	Fall '15	Unsaid	Unsaid	350	28	53
105	Fall '15	Male	25	110	21	43
106	Fall '15	Male	21	465	37	56
107	Fall '15	Unsaid	Unsaid	0	0	0
108	Fall '15	Unsaid	Unsaid	213	39	48
109	Fall '15	Unsaid	Unsaid	110	28	42
110	Fall '15	Male	19	110	21	24
111	Fall '15	Unsaid	Unsaid	1166	101	143
112	Fall '15	Unsaid	Unsaid	208	56	92
113	Fall '15	Unsaid	Unsaid	155	22	29
114	Fall '15	Unsaid	Unsaid	325	51	64
115	Fall '15	Unsaid	Unsaid	290	39	53
116	Fall '15	Unsaid	Unsaid	10	0	0
117	Fall '15	Male	39	530	147	168
118	Fall '15	Unsaid	Unsaid	496	37	55
119	Fall '15	Male	19	181	26	40
120	Fall '15	Female	18	600	129	168
121	Fall '15	Unsaid	Unsaid	0	0	0
122	Fall '15	Unsaid	Unsaid	20	3	3
123	Fall '15	Male	20	326	35	55
124	Fall '15	Unsaid	Unsaid	140	16	25

125	Fall '15	Unsaid	Unsaid	0	0	0
126	Fall '15	Unsaid	Unsaid	0	0	0
127	Fall '15	Unsaid	Unsaid	135	16	27
128	Fall '15	Unsaid	Unsaid	0	0	0
129	Fall '15	Unsaid	Unsaid	165	21	32
130	Fall '15	Unsaid	Unsaid	170	22	29
131	Fall '15	Unsaid	Unsaid	870	67	103
132	Fall '15	Unsaid	Unsaid	0	0	0
133	Fall '15	Unsaid	Unsaid	300	67	81
134	Fall '15	Unsaid	Unsaid	160	17	25
135	Fall '15	Unsaid	Unsaid	300	72	106
136	Fall '15	Unsaid	Unsaid	1488	92	134
137	Fall '15	Unsaid	Unsaid	1045	86	110
138	Fall '15	Unsaid	Unsaid	460	31	40
139	Fall '15	Male	19	288	46	55
140	Fall '15	Unsaid	Unsaid	0	0	0
141	Fall '15	Unsaid	Unsaid	0	0	0
142	Fall '15	Unsaid	Unsaid	0	0	0
143	Fall '15	Unsaid	Unsaid	175	22	31
144	Fall '15	Unsaid	Unsaid	948	98	126
145	Fall '15	Unsaid	Unsaid	1025	84	97
146	Fall '15	Unsaid	Unsaid	470	34	66
147	Fall '15	Unsaid	Unsaid	455	49	58

148	Fall '15	Female	19	40	6	10
149	Fall '15	Female	19	476	33	45
150	Fall '15	Unsaid	Unsaid	445	54	93
151	Fall '15	Male	20	330	31	55
152	Fall '15	Unsaid	Unsaid	110	16	19
153	Fall '15	Unsaid	Unsaid	495	38	46
154	Fall '15	Male	21	165	20	31
155	Fall '15	Unsaid	Unsaid	696	170	211
156	Fall '15	Female	21	2023	163	177
157	Fall '15	Unsaid	Unsaid	10	0	0
158	Fall '15	Male	20	190	31	41
159	Fall '15	Female	22	600	188	250
160	Fall '15	Male	21	357	40	49
161	Fall '15	Male	26	120	86	110
162	Fall '15	Unsaid	Unsaid	0	0	0
163	Fall '15	Unsaid	Unsaid	10	15	28
164	Fall '15	Unsaid	Unsaid	155	35	48
165	Fall '15	Female	20	3387	181	205
166	Fall '15	Unsaid	Unsaid	400	82	110
167	Fall '15	Unsaid	Unsaid	0	0	0
168	Fall '15	Unsaid	Unsaid	150	22	42
169	Fall '15	Unsaid	Unsaid	200	25	36
170	Fall '15	Unsaid	Unsaid	430	93	129



171	Fall '15	Unsaid	Unsaid	300	105	141
172	Fall '15	Unsaid	Unsaid	10	6	12
173	Fall '15	Unsaid	Unsaid	0	0	0
174	Fall '15	Female	22	2652	158	176
175	Fall '15	Unsaid	Unsaid	110	17	19
176	Fall '15	Unsaid	Unsaid	1126	73	81
177	Fall '15	Unsaid	Unsaid	794	57	82
178	Fall '15	Unsaid	Unsaid	176	37	50
179	Fall '15	Male	20	3431	190	220
180	Fall '15	Unsaid	Unsaid	190	130	181
181	Fall '15	Male	21	280	36	42

# Appendix B

## Decimal To Binary Conversions Performance

Table B.1: User's performance in-game for decimal to binary conversion questions.

User	Decimal / Binary Conversions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	27	7	29
3	0	0	0
4	16	7	16
5	7	21	9
6	5	2	5

7	16	15	20
8	0	0	0
9	8	5	9
10	35	27	41
11	12	5	13
12	23	4	23
13	0	0	0
14	6	0	6
15	13	0	13
16	8	3	8
17	11	5	11
18	13	32	17
19	2	0	2
20	12	10	13
21	21	20	23
22	5	20	7
23	28	23	32
24	0	0	0
25	28	16	32
26	9	1	9
27	0	0	0
28	4	0	4
29	0	0	0

30	13	5	17
31	2	3	6
32	3	4	5
33	0	0	0
34	2	3	3
35	0	0	0
36	1	2	2
37	0	0	0
38	0	0	0
39	15	2	16
40	2	4	5
41	4	2	7
42	9	1	9
43	3	2	5
44	8	8	13
45	0	0	0
46	11	3	12
47	2	0	2
48	10	2	10
49	2	6	3
50	19	67	27
51	5	7	11
52	3	6	9

53	0	0	0
54	7	8	9
55	8	10	8
56	15	7	18
57	0	0	0
58	3	1	3
59	0	0	0
60	9	12	11
61	3	1	3
62	3	28	9
63	5	2	5
64	17	1	18
65	10	3	11
66	6	1	7
67	5	0	6
68	16	5	17
69	0	0	0
70	1	2	2
71	15	67	28
72	0	0	0
73	0	0	0
74	2	0	2
75	0	0	0

76	0	0	0
77	6	1	6
78	10	11	12
79	7	2	7
80	9	0	9
81	0	0	0
82	17	5	17
83	0	0	0
84	1	0	1
85	2	2	5
86	5	3	5
87	2	0	2
88	0	0	0
89	6	3	6
90	3	0	3
91	9	4	9
92	5	1	6
93	12	0	12
94	10	1	10
95	0	0	0
96	2	5	3
97	4	0	4
98	14	15	16

99	0	0	0
100	2	1	2
101	20	14	21
102	22	0	22
103	0	0	0
104	7	4	9
105	4	10	5
106	3	2	3
107	0	0	0
108	8	1	8
109	8	3	10
110	6	4	7
111	19	14	20
112	15	34	20
113	8	4	9
114	8	2	9
115	6	1	6
116	0	0	0
117	22	7	25
118	6	1	8
119	5	12	7
120	19	56	28
121	0	0	0

122	1	1	1
123	8	2	9
124	3	0	4
125	0	0	0
126	0	0	0
127	6	3	6
128	0	0	0
129	5	10	7
130	6	6	6
131	7	3	9
132	0	0	0
133	6	14	9
134	5	3	6
135	2	6	7
136	15	31	20
137	12	1	12
138	2	0	2
139	11	8	12
140	0	0	0
141	0	0	0
142	0	0	0
143	8	4	8
144	12	6	13



145	10	4	11
146	5	0	5
147	4	3	5
148	2	0	2
149	6	2	7
150	12	2	12
151	5	7	5
152	6	0	6
153	4	0	4
154	7	3	7
155	36	12	37
156	25	20	28
157	0	0	0
158	7	0	7
159	27	71	47
160	4	3	5
161	20	6	22
162	0	0	0
163	4	8	7
164	7	6	7
165	32	6	34
166	7	0	8
167	0	0	0

168	6	5	9
169	4	3	5
170	18	7	20
171	25	21	29
172	1	0	1
173	0	0	0
174	27	5	27
175	4	2	4
176	10	9	10
177	7	9	8
178	14	16	16
179	30	46	35
180	30	13	31
181	7	2	8

# Appendix C

## Binary to Octal Conversions Performance

Table C.1: User's performance in-game for binary to octal conversion questions.

User	Binary / Octal Conversions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	39	8	40
3	0	0	0
4	10	4	11
5	5	26	9
6	1	0	1

7	8	16	13
8	0	0	0
9	1	0	1
10	41	10	44
11	10	8	15
12	28	6	28
13	0	0	0
14	4	0	4
15	12	2	13
16	9	5	9
17	16	1	16
18	12	2	12
19	5	0	5
20	9	0	9
21	13	3	14
22	9	13	12
23	20	3	21
24	0	0	0
25	27	11	30
26	8	2	9
27	0	0	0
28	5	2	5
29	0	0	0

30	1	4	16
31	4	21	10
32	5	3	5
33	0	0	0
34	1	14	3
35	0	0	0
36	7	2	8
37	0	0	0
38	0	0	0
39	13	5	14
40	6	8	11
41	6	5	8
42	0	0	0
43	0	11	3
44	4	14	14
45	0	0	0
46	5	1	6
47	4	0	4
48	5	0	5
49	2	0	3
50	13	5	14
51	5	4	10
52	10	4	12

53	0	0	0
54	5	0	6
55	8	9	9
56	11	3	11
57	0	0	0
58	2	0	2
59	0	0	0
60	1	3	3
61	3	0	3
62	2	5	9
63	2	4	4
64	15	0	15
65	7	0	7
66	6	1	6
67	1	2	3
68	19	11	21
69	0	0	0
70	2	0	2
71	27	15	31
72	0	0	0
73	0	0	0
74	6	11	7
75	0	0	0

76	0	0	0
77	3	1	3
78	6	12	7
79	0	0	0
80	11	1	11
81	0	0	0
82	8	0	8
83	0	0	0
84	1	2	3
85	2	1	5
86	7	2	7
87	2	0	2
88	0	0	0
89	2	0	2
90	3	0	3
91	3	0	3
92	1	3	2
93	10	8	13
94	6	0	6
95	0	0	0
96	1	6	4
97	5	0	5
98	7	7	9

99	0	0	0
100	4	1	4
101	18	5	22
102	8	3	8
103	0	0	0
104	0	9	5
105	4	21	8
106	2	3	2
107	0	0	0
108	12	9	14
109	4	2	7
110	2	0	2
111	12	44	18
112	15	21	21
113	6	8	8
114	4	0	4
115	7	2	7
116	0	0	0
117	33	4	34
118	3	1	6
119	7	13	9
120	28	1	28
121	0	0	0



122	2	0	2
123	3	11	8
124	2	0	2
125	0	0	0
126	0	0	0
127	2	1	4
128	0	0	0
129	7	3	8
130	3	4	5
131	4	28	10
132	0	0	0
133	5	1	6
134	2	0	2
135	6	11	9
136	11	4	14
137	9	5	11
138	4	5	5
139	6	1	6
140	0	0	0
141	0	0	0
142	0	0	0
143	3	3	5
144	15	6	16

145	5	6	7
146	2	4	3
147	3	1	3
148	2	0	2
149	3	3	3
150	3	6	9
151	3	1	4
152	2	0	2
153	4	11	5
154	7	0	8
155	21	8	25
156	23	4	23
157	0	0	0
158	5	0	5
159	27	21	33
160	6	5	6
161	8	1	10
162	0	0	0
163	3	0	3
164	3	6	5
165	24	28	28
166	5	33	10
167	0	0	0

168	2	1	7
169	7	0	7
170	11	20	19
171	8	30	14
172	0	10	2
173	0	0	0
174	21	11	23
175	1	0	1
176	9	0	9
177	1	1	2
178	6	12	7
179	32	11	33
180	20	15	32
181	6	1	6

# Appendix D

## Binary to Hexadecimal Conversion Performance

Table D.1: User's performance in-game for binary to hexadecimal conversion questions.

User	Binary / Hexadecimal Conversions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	41	5	43
3	0	0	0
4	10	5	11
5	12	13	13
6	5	3	5

7	13	14	17
8	0	0	0
9	3	8	6
10	37	26	43
11	11	10	14
12	26	31	32
13	0	0	0
14	1	3	2
15	7	2	8
16	4	15	7
17	16	2	16
18	14	5	15
19	3	0	3
20	16	4	17
21	18	11	21
22	6	30	11
23	16	11	20
24	0	0	0
25	27	21	33
26	12	3	14
27	0	0	0
28	0	3	1
29	0	0	0

30	7	9	15
31	4	4	5
32	8	2	9
33	0	0	0
34	1	7	4
35	0	0	0
36	5	10	9
37	0	0	0
38	0	0	0
39	7	4	10
40	4	17	9
41	4	4	7
42	0	9	2
43	0	11	4
44	7	29	18
45	0	0	0
46	7	3	10
47	0	0	0
48	6	2	7
49	1	10	4
50	12	25	19
51	0	29	6
52	7	5	9

53	0	0	0
54	4	3	4
55	9	6	12
56	5	11	8
57	0	0	0
58	1	5	2
59	0	0	0
60	3	20	10
61	0	0	0
62	5	8	10
63	3	7	5
64	16	9	19
65	4	3	5
66	1	1	3
67	4	19	9
68	6	17	13
69	0	0	0
70	1	0	1
71	25	16	30
72	0	0	0
73	0	0	0
74	2	0	2
75	0	0	0

76	0	0	0
77	5	0	5
78	9	15	12
79	0	0	0
80	6	2	6
81	0	0	0
82	10	9	12
83	0	0	0
84	4	2	4
85	4	3	7
86	3	12	8
87	4	9	4
88	0	0	0
89	5	4	5
90	4	0	4
91	3	1	3
92	7	2	8
93	11	17	16
94	1	12	4
95	0	0	0
96	6	5	8
97	2	2	3
98	3	12	8



99	0	0	0
100	4	0	4
101	17	11	22
102	13	3	14
103	0	0	0
104	0	5	5
105	1	32	5
106	1	2	3
107	0	0	0
108	8	6	10
109	0	3	2
110	3	4	3
111	16	18	20
112	9	7	13
113	3	4	3
114	8	8	13
115	3	15	7
116	0	0	0
117	23	11	26
118	4	0	6
119	6	7	7
120	18	0	19
121	0	0	0

122	0	0	0
123	2	7	6
124	6	4	7
125	0	0	0
126	0	0	0
127	3	1	4
128	0	0	0
129	3	10	6
130	3	3	5
131	12	41	16
132	0	0	0
133	10	1	11
134	1	29	4
135	14	5	15
136	6	36	15
137	5	4	9
138	3	3	4
139	20	5	21
140	0	0	0
141	0	0	0
142	0	0	0
143	2	1	4
144	25	17	30

145	5	5	7
146	0	8	2
147	6	6	7
148	0	4	2
149	2	1	2
150	7	14	12
151	1	1	2
152	2	3	3
153	3	1	3
154	1	14	5
155	34	13	41
156	25	11	27
157	0	0	0
158	4	3	5
159	12	31	20
160	9	11	11
161	17	7	22
162	0	0	0
163	5	17	8
164	8	14	11
165	30	6	31
166	10	12	15
167	0	0	0

168	1	9	6
169	3	3	4
170	3	15	9
171	17	20	21
172	2	20	4
173	0	0	0
174	16	7	19
175	1	2	2
176	8	4	9
177	8	3	9
178	12	13	14
179	37	10	37
180	18	25	28
181	3	1	3

# Appendix E

## 2's Complement Questions Performance

Table E.1: User's performance in-game for 2's complement questions.

User	2's Complement Questions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	24	9	25
3	0	0	0
4	31	26	33
5	20	4	20
6	0	6	1

7	24	44	30
8	0	0	0
9	0	0	0
10	31	14	33
11	30	31	31
12	17	13	19
13	0	0	0
14	0	0	0
15	22	7	25
16	0	0	0
17	25	11	26
18	0	0	0
19	0	0	0
20	32	55	39
21	27	21	29
22	24	24	26
23	37	46	42
24	0	0	0
25	46	25	49
26	0	0	0
27	0	0	0
28	0	0	0
29	0	0	0

30	0	0	0
31	8	81	18
32	1	33	8
33	0	0	0
34	10	32	14
35	0	0	0
36	8	1	8
37	0	0	0
38	0	0	0
39	22	32	25
40	7	14	11
41	3	1	5
42	1	6	2
43	0	16	3
44	1	20	8
45	0	0	0
46	4	5	9
47	2	3	2
48	3	27	7
49	6	2	6
50	31	102	44
51	18	10	20
52	4	4	6

53	0	0	0
54	4	10	6
55	9	16	12
56	2	118	15
57	0	0	0
58	6	1	6
59	0	0	0
60	0	30	3
61	5	0	5
62	3	47	9
63	6	20	10
64	16	9	17
65	3	19	5
66	4	0	4
67	4	10	5
68	14	22	20
69	0	0	0
70	1	0	1
71	35	50	42
72	0	0	0
73	0	0	0
74	1	23	4
75	0	0	0



76	0	0	0
77	4	10	5
78	8	24	14
79	1	8	2
80	2	26	5
81	0	0	0
82	1	14	3
83	0	0	0
84	3	1	3
85	2	4	7
86	2	15	4
87	6	0	6
88	0	0	0
89	3	4	3
90	3	5	4
91	0	3	2
92	1	3	1
93	20	44	33
94	7	4	7
95	0	0	0
96	8	20	13
97	3	0	3
98	30	31	31

99	0	0	0
100	4	1	4
101	26	24	31
102	23	14	25
103	0	0	0
104	1	16	7
105	1	37	5
106	12	24	26
107	0	0	0
108	0	14	3
109	3	13	5
110	5	3	6
111	23	88	32
112	1	71	11
113	0	10	1
114	5	4	6
115	4	27	7
116	0	0	0
117	20	16	29
118	9	1	11
119	0	20	4
120	22	39	27
121	0	0	0

122	0	0	0
123	4	7	5
124	1	21	5
125	0	0	0
126	0	0	0
127	0	8	2
128	0	0	0
129	0	23	3
130	2	13	5
131	15	73	26
132	0	0	0
133	16	3	21
134	3	16	5
135	23	13	30
136	22	64	34
137	13	8	22
138	9	37	15
139	2	2	3
140	0	0	0
141	0	0	0
142	0	0	0
143	1	5	2
144	13	59	23

145	20	14	23
146	9	37	17
147	14	6	15
148	0	3	1
149	8	2	8
150	6	8	12
151	1	35	6
152	3	0	3
153	10	11	10
154	0	19	4
155	21	79	39
156	30	13	33
157	0	0	0
158	0	5	1
159	35	31	42
160	4	6	7
161	6	16	11
162	0	0	0
163	0	34	4
164	6	21	9
165	26	97	37
166	21	99	31
167	0	0	0

168	3	0	7
169	5	2	5
170	18	88	32
171	19	79	31
172	0	10	1
173	0	0	0
174	37	14	41
175	6	1	6
176	15	40	19
177	10	107	27
178	3	0	3
179	42	9	43
180	17	15	22
181	1	4	3

# Appendix F

## Binary Arithmetic Performance

Table F.1: User's performance in-game for binary arithmetic questions.

User	Binary Arithmetic Questions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	16	3	16
3	0	0	0
4	15	6	15
5	12	12	13
6	1	1	1
7	11	44	18
8	0	0	0

9	0	0	0
10	14	32	20
11	11	21	20
12	4	31	10
13	0	0	0
14	0	0	0
15	11	22	15
16	0	0	0
17	11	11	12
18	0	0	0
19	0	0	0
20	17	1	17
21	12	42	19
22	8	1	9
23	6	22	9
24	0	0	0
25	13	13	17
26	2	86	12
27	0	0	0
28	0	0	0
29	0	0	0
30	0	0	0
31	6	51	13

32	6	12	8
33	0	0	0
34	11	5	11
35	0	0	0
36	2	6	4
37	0	0	0
38	0	0	0
39	12	18	17
40	3	8	6
41	2	4	4
42	3	7	5
43	1	9	3
44	16	33	33
45	0	0	0
46	10	7	13
47	5	4	6
48	5	9	7
49	4	1	4
50	21	142	38
51	17	28	25
52	4	8	7
53	0	0	0
54	3	22	8



55	14	8	17
56	7	30	13
57	0	0	0
58	2	0	2
59	0	0	0
60	0	10	2
61	3	4	3
62	7	12	11
63	3	12	6
64	21	28	26
65	5	32	8
66	5	25	9
67	8	3	9
68	5	3	6
69	0	0	0
70	4	8	6
71	24	45	32
72	0	0	0
73	0	0	0
74	4	11	5
75	0	0	0
76	0	0	0
77	3	8	4

78	9	46	16
79	15	7	15
80	1	29	5
81	0	0	0
82	11	27	15
83	0	0	0
84	4	3	6
85	6	19	11
86	5	9	6
87	3	1	3
88	0	0	0
89	2	8	3
90	1	9	3
91	6	4	6
92	1	17	4
93	12	35	24
94	5	6	7
95	0	0	0
96	9	35	18
97	2	1	2
98	10	9	12
99	0	0	0
100	1	0	1

101	21	32	32
102	21	0	21
103	0	0	0
104	7	15	12
105	3	37	8
106	7	5	10
107	0	0	0
108	6	11	7
109	5	4	7
110	1	0	1
111	16	78	29
112	6	47	14
113	4	13	5
114	15	18	20
115	4	34	9
116	0	0	0
117	17	17	21
118	7	11	11
119	5	7	7
120	28	36	34
121	0	0	0
122	0	0	0
123	9	21	13

124	1	4	2
125	0	0	0
126	0	0	0
127	4	13	8
128	0	0	0
129	4	12	5
130	6	4	6
131	16	41	21
132	0	0	0
133	13	3	15
134	4	2	4
135	8	46	20
136	15	53	24
137	28	7	33
138	9	4	10
139	3	2	4
140	0	0	0
141	0	0	0
142	0	0	0
143	2	15	6
144	18	19	21
145	30	13	33
146	5	90	19

147	11	27	15
148	0	0	0
149	8	14	11
150	15	31	23
151	11	64	21
152	3	0	3
153	8	6	9
154	2	11	4
155	26	38	32
156	30	13	33
157	0	0	0
158	15	25	18
159	49	104	63
160	10	24	13
161	15	22	23
162	0	0	0
163	1	17	4
164	3	21	7
165	40	21	42
166	19	41	23
167	0	0	0
168	1	2	2
169	4	20	6

170	31	9	33
171	15	59	25
172	1	11	2
173	0	0	0
174	29	40	36
175	3	3	3
176	16	0	16
177	12	22	16
178	0	59	7
179	31	27	34
180	13	50	30
181	13	0	13

# Appendix G

## Floating Point Performance

Table G.1: User's performance in-game for floating point questions.

User	Floating Point Questions		
ID	Correct Answers	Incorrect Answers	Total Questions
1	1	1	1
2	23	3	23
3	0	0	0
4	9	38	13
5	7	17	10
6	0	0	0
7	19	27	23
8	0	0	0

9	0	0	0
10	24	17	26
11	16	25	25
12	10	20	14
13	0	0	0
14	0	0	0
15	11	39	15
16	0	0	0
17	10	3	10
18	0	0	0
19	1	12	2
20	10	8	12
21	15	36	21
22	7	27	11
23	11	53	17
24	0	0	0
25	35	16	35
26	3	21	5
27	0	0	0
28	0	0	0
29	0	0	0
30	0	0	0
31	14	33	19



32	6	43	13
33	0	0	0
34	7	14	8
35	0	0	0
36	3	15	9
37	0	0	0
38	0	0	0
39	13	6	14
40	1	23	5
41	3	7	7
42	3	10	4
43	2	10	3
44	41	34	44
45	0	0	0
46	10	7	10
47	4	0	4
48	0	34	6
49	2	12	4
50	24	137	38
51	22	41	29
52	1	11	3
53	0	0	0
54	8	10	9

55	10	16	12
56	10	57	15
57	0	0	0
58	2	5	3
59	0	0	0
60	6	59	12
61	1	0	1
62	0	0	0
63	2	10	3
64	36	15	38
65	3	19	5
66	17	44	22
67	3	39	8
68	8	4	9
69	0	0	0
70	7	1	7
71	55	47	59
72	0	0	0
73	0	0	0
74	3	16	5
75	0	0	0
76	0	0	0
77	5	14	8

78	9	42	17
79	4	18	6
80	2	21	4
81	0	0	0
82	6	91	15
83	0	0	0
84	5	4	5
85	3	2	4
86	8	18	13
87	0	3	1
88	0	0	0
89	4	2	4
90	2	15	5
91	8	4	10
92	4	0	4
93	24	21	29
94	5	2	5
95	0	0	0
96	15	26	17
97	1	11	3
98	13	19	16
99	0	0	0
100	1	0	1

101	12	91	29
102	24	27	33
103	0	0	0
104	13	11	15
105	8	26	12
106	12	6	12
107	0	0	0
108	5	6	6
109	8	23	11
110	4	6	5
111	15	95	24
112	10	20	13
113	1	15	3
114	11	5	12
115	15	25	17
116	0	0	0
117	32	18	33
118	8	14	13
119	3	17	6
120	14	124	32
121	0	0	0
122	0	0	0
123	9	43	14

124	3	2	5
125	0	0	0
126	0	0	0
127	1	5	3
128	0	0	0
129	2	6	3
130	2	1	2
131	13	89	21
132	0	0	0
133	17	4	19
134	2	10	4
135	19	33	25
136	23	36	27
137	19	23	23
138	4	2	4
139	4	28	9
140	0	0	0
141	0	0	0
142	0	0	0
143	6	8	6
144	15	89	23
145	14	30	16
146	13	67	20

147	11	13	13
148	2	3	3
149	6	18	14
150	11	46	25
151	10	45	17
152	0	6	2
153	9	33	15
154	3	2	3
155	32	30	37
156	30	28	33
157	0	0	0
158	0	47	5
159	38	60	45
160	7	2	7
161	20	20	22
162	0	0	0
163	2	0	2
164	8	8	9
165	29	35	33
166	20	40	23
167	0	0	0
168	9	20	11
169	2	56	9

170	12	28	16
171	21	16	21
172	2	0	2
173	0	0	0
174	28	10	30
175	2	8	3
176	15	34	18
177	19	10	20
178	2	16	3
179	18	202	38
180	32	40	38
181	6	5	9

# Appendix H

## Exam Performance

### H.1 Summer 2015

Number of students that played the game: 15

Number of student that did not play the game: 13



Table H.1: Percentage of students with correct answers in exam 1 and exam 2 (Summer 2015).

Question Types	Played Game		Did Not Play Game	
	1st Test	2nd Test	1st Test	2nd Test
Bin/Dec Conversion	100.00%	100.00%	76.92%	69.23%
Hex/Oct/Bin Conversion	93.33%	93.33%	88.46%	84.62%
2's complement	40.00%	80.00%	38.46%	61.54%
Binary Arithmetic	73.33%	80.00%	69.23%	73.08%
Floating Point	63.33%	96.67%	53.85%	65.38%

## H.2 Fall 2015

### H.2.1 First Exam

Number of students that played the game: 51

Number of students that didn't play the game: 89

Table H.2: Percentage of students with correct answers in first exam (Fall 2015).

Question Type	Played Game	Did Not Play
Number Representation	84.31%	69.66%
Number Conversion	88.24%	80.90%
Signed Numbers	21.57%	13.48%
Floating Point - Q1	56.86%	32.58%
Floating Point - Q2	50.98%	39.33%

## H.2.2 Final Exam

Number of students that played the game consistently: 52

Number of students that played the game inconsistently: 58

Number of students that did not play the game: 14

Table H.3: Percentage of students with correct answers in final exam (Fall 2015).

Question Type	Played Continuously	Played Inconsistently	Didn't Play
Number Representation	90.38%	91.38%	78.57%
Number Conversion	82.69%	89.66%	85.71%
Signed Numbers	61.54%	65.52%	50.00%
Floating Point Q1	88.46%	84.48%	85.71%
Floating Point Q2	73.08%	62.07%	35.71%
Floating Point Q3	61.54%	51.72%	50.00%

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