

The Development and Effect of Serious Games

Undergraduate Research Thesis

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By: David Burl

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Committee:

Rajiv Ramnath, Advisor

Jay Ramnathan

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I. Abstract

Serious games - games that are intended to educate in addition to simply entertain - can be a valuable asset in an effort to educate teenagers and young adults, who prefer learning through programs that they can control, such as video games (Corriveau, Shi, 2010). In this thesis we present the development of this mobile multi-platform serious game intended to teach the basic information about asthma to teenagers and young adults. We review the design of the game and the mobile technologies used to create the game. We present conclusions based on observations made while interviewees played the game, and detail the changes made to the game based on these observations. Each interviewee also provided feedback on the game, and completed several assessments to measure their knowledge of asthma before and after playing the game. We review the knowledge each interviewee gained from the interaction with the game, and draw and present conclusions based on the background each subject comes from.

II. Acknowledgements

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III. Vita

2009-2010, 2012-2013The Ohio State University Honors
June 2012-August 20 Ohio Computer Library Center, Technical Intern
2009-Present Medalist Scholarship, The Ohio State University

Fields of Study

Major Field: Computer Science and Engineering

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1.0 Introduction

1.1 Background and Motivation

Video games are an increasingly popular and important part of both the entertainment industry and the everyday lives of people around the globe. This growth is evident from the predicted growth of the industry in the coming years - from \$67 Billion in 2012 to \$82 Billion in 2017 (Gaudiosi, 2012), which is indicative of a society that is more connected and more interactive than ever before. While the gaming industry is largely an industry dedicated to entertainment, there is a growing use of games to do more than simple entertain.

These games, known as serious games, are games that are both “serious”, and thus have a non-entertaining purpose, and “games”, meaning they fit within the structure of a game (Djaouti, Alvarez, & Jessel, 2011). Users playing serious games created for the purpose of education have been found to show significant improvement in their knowledge and awareness of the subject matter that these games cover (Guillén-Nieto, 2012). By applying the educational potential of serious games, it is possible to educate the game-playing populace in matters that may improve their way of life, or otherwise understand the subject which a game may cover better in order to better relate to and understand others.

One possible application of serious gaming is when attempting to improve the life of people with asthma. While those with the knowledge of the treatment asthma are able

manage their asthma, few individuals possess this knowledge due to the challenge in providing adequate asthma education (Holzheimer, Mohay, & Masters, 1997). Given that many children in this projects target age group, consisting of teenagers to young adults, may be uninterested in learning about their asthma through traditional methods, such as through interaction with their doctor or written material, the usage of a game to help learn about the relationship between the triggers that cause asthma attacks and the defense against these triggers promotes greater understanding of asthma.

While other methods of educational entertainment exist, such as educational television or educational radio, neither medium contains the interactivity that allows serious gaming to not only present ideas for the user to learn, but also interact with those ideas and draw conclusions from such interactions. This is because educational games are a form of active learning, which has been shown to vastly improve retention and understanding of the material been taught (Prince, 2013).

Given a target audience consisting of teenagers and young adults, the creation of such an games should be targeted towards mediums that teenagers and young adults are most likely to use and will use in the years ahead. By far the fastest growing consumer technology is the smartphone industry, which is projected to continue to grow during the year 2013 (CEA, 2013). The availability of a smartphone allows it to be used anywhere: during public transport, in a waiting room, at home and at work. The smartphone is also more than a simple communication device, as it is one of the main platforms used to play video games: 33% of gamers play games on their smartphones (ESA, 2012).

1.2 Contribution

This research examines the how well a serious game developed for the purpose of education allows for a greater understanding of the subject material. This is accomplished by examining what aspects of this game allows subjects to more easily understand asthma, and what aspects of a subjects background allow them to more easily understand asthma. Furthermore, this research examines the technologies used for multi platform mobile development, and details how well they support the development of serious games on this platform. This is accomplished through a two step process.

First, an serious game is developed with the help of a Senior Capstone team at The Ohio State University for use as a part of a larger application targeted towards asthma management developed for the Ohio Department of Health. A serious game is chosen for the task because it can more easily convey the relationships between a the causes of asthma and ways to treat these causes. Development of the serious game is achieved first by identifying the goals of the serious game and designing gameplay which accomplishes those goals through an end user's interaction with the game. Next, development is completed on the core framework of the game to support the goals previously defined. Once completed, game specific objects are completed while bug testing takes place. Finally, the game mechanics are play tested by members of the development team.

Second, the developed serious game is play tested by interviewing users not previously familiar with the game in order to judge effectiveness and enjoyment. This

achieved by first presenting the interviewee with a questionnaire assessing details about their background and current understanding of asthma. Users are then asked to play through the first two levels of the game. Next, interviewees are given a second set of questionnaires assessing their opinion of the game and obtaining their new level of understanding about asthma. Lastly, users are assessed on their understanding of asthma one week later.

1.3 Description of Remaining Chapters

Chapter 2.1 defines serious games and discusses the different types of serious games. Chapter 2.2 relates various methodologies that might be used when designing and building serious games. Chapter 3.1 details the requirements which were set in place to create the serious game. Chapter 3.2 discusses the game design and code design for the developed serious game. Chapter 3.3 presents the structure of the interview for the serious game. Chapter 4.1 discusses the findings from the playtesting that occurred during interviews. Chapter 4.2 details how well the game teaches users about asthma. Chapter 4.3 presents additional information found about the technology used to create the game. Chapter 5.1 presents overall conclusions derived from the results. Chapter 5.2 relates future work that may be done to further improve the project.

2.0 Review of Literature

2.1 Problem Analysis

To define and describe serious games, we reference a book defining and explaining serious games (Michael & Chen, 2006), a paper on classifying serious games (Djaouti, Alvarez, & Jessel, 2011), and an articles discussing serious gaming with young people (Corriveau, & Shi, 2010).

2.1.1 Definition of Serious Games

Michael and Chen define serious gaming as a game in which education is the primary goal, rather than entertainment (Michael & Chen, 2006). Djaouti, Alvarez and Jessel break the term up into its parts, “serious” and “game”, and then define serious games as a “game” which has a non-entertaining primary purpose, thus making it “serious” (Djaouti, Alvarez, & Jessel, 2011). From these definitions, it is apparent that serious gaming is a broad term covering many different categories.

2.1.2 Categorizing Serious Games

In order to more specifically classify games, Djaouti, Alvarez and Jessel classify serious games into more specific categories based on the purpose of the game: Games for Health, Advergaming, Games for Training, Games for Education, Games for Science and Research, Production, and finally, Games as Work (Djaouti, Alvarez, & Jessel, 2011). These categories highlight the various potential uses of serious games, which allow users

to be trained, rehabilitated, and educated.

While the categorization of the “serious” part of serious games is important, as it defines the market of a serious game, so to is the categorization of the “games” part. This is achieved by splitting the components of a game into a model known as the Game/Purpose/Scope Model (G/P/S Model). The Game portion of the G/P/S Model refers to the gameplay, or how the game is played. This is important as it defines the players minute-to-minute experience with the game, and must be both be enjoyable and enable learning related to the purpose. The Purpose portion of the G/P/S Model refers to the purpose of the game, apart from entertainment. This purpose is likely related to to the category of the game; in serious games based on education, for example, the purpose to educate on a particular subject. The last portion of the G/P/S Model is the Scope. The scope describes the use of a game, such as the target market (Djaouti, Alvarez, & Jessel, 2011).

Since this research focuses on the use of a educational game about health, it is important to understand both the categories of “Games for Education” and “Games for Health”. Games which fall under the Games for Education category seek to teach players new material, and are more commonly used in the classroom with teachers and other governing bodies. Games which fall under the Games for Health category can have multiple purposes. Many games in this category are used for mental and physical rehabilitation, requiring interaction beyond those traditionally used. In addition to rehabilitation, Games for Health may also refer to health education games, which aim to

teach the player and promote changes in their behavior to improve health. (Michael & Chen, 2006) This sub-category intersects heavily with Games for Education, as it uses methods for education often found in games which are categorized as Educational Games, and it is within this intersection that this research takes place.

2.1.3 Understanding Serious Games

Despite the focus on education for the players of these serious games, it is important that serious games remain fun. Surveys have indicated that the importance of a serious game being fun is important; when asked the question, over 80% of respondents indicated that a serious game being fun either “important” or “very important” (Michael & Chen, 2006). In controlled circumstances where players are specifically tasked with playing and completing a game, such as in academic courses, the amount of enjoyment experienced by players may not be as important, since completion of a game and learning the content taught by the game is mandatory. In contrast, when developing serious games for public release it is more important to ensure that players enjoy the game, as it may be more enjoyable to use time spent playing the game on more enjoyable, less educational activities. Voluntary play is in fact most desirable, as it allows players to “develop and internalize rules for success they can intuitively apply to the real world” (Michael & Chen, 2006).

The importance of serious gaming is also increasing due to the technological aptitude of modern children, teenagers, and young adults. This increasing technological aptitude has led them to wish to learn “through programs they can control (such as video

games)” (Corriveau, Shi, 2010). It is therefore important to improve the overall understanding of the ability for serious games to aid in learning.

2.2 Problem Solution

To describe the steps and details of describing a serious game, we again reference a book defining and explaining serious games (Michael & Chen, 2006) as well as an article on training effectiveness in serious gaming (Greitzer, Kuchar, & Huston, 2007), a book describing the development of serious games (Bergeron, 2006), and an article discussing the usage of serious gaming in a health context (Bomark, Evertsen, Brox, Hirche, & Yliräisänen-Seppänen).

2.2.1 Designing Serious Games

When designing serious games, there are a number of design challenges to address not normally present when design non-serious games. One such challenge is the powerful hardware typically targeted towards games is not available to those who wish to develop serious games. This is usually due to the environments serious games are used in: while instructors may only have limited and low-end resources available for use in a learning environment, a dedicated gaming console more often used to play non-serious video games have much more power.

Several publications also contain guidance that help in the development of serious games. Greitzer, Kuchar and Hoston have devised a list of five principles to use when designing serious games. The first, *simulating semantic knowledge*, directs that games

should relate material from within the game to existing experiences that the player may have. The second, *managing the learners cognitive load*, directs that material should be organized into small chunks in order to aid in learning. The third, *immersing the learner in problem-centered activities*, directs that games should allow players to work on meaningful tasks. The fourth, *emphasizing interactive experiences*, directs that the game should directly interact with the material to be learned in order to effectively learn it. The last, *engaging the learner*, directs that gameplay be engaging - not too difficult and not too easy (Greitzer, Kuchar, & Huston, 2007). Following these directives allows for the creation of a serious game that is both enjoyable to play and educational.

2.2.2 Building Serious Games

When building serious games it may not be possible to obtain sufficient time or budget to create a game from scratch. It may therefore be advisable to instead either use repurposed commercial off-the-shelf games, or use modified - or modded - games. Repurposed commercial off-the-shelf games are games which are unmodified from their original state, but can still be used to educate users in a manner similar to those which serious games use. These games are often used as prototypes for yet to be developed serious games. Modified games are games which change a commercial game created for non-serious gaming purposes into a new game with the ability to teach. (Bergeron, 2006) These mods may use gameplay mechanics from the original games, or choose to develop new ones to better suit the style of the modified game. While these alternatives to developing a full game may be useful under special conditions, most often serious game

developers must build the game from the ground up.

2.2.3 Researching Serious Games

In order to study serious games, it is important to evaluate their ability to effectively teach. This can aid both in comparing multiple serious games to determine which can best teach a concept, or can be used to compare serious gaming to traditional methods of learning which do not involve the use of a game. It is therefore unfortunate that it is difficult to assess how much has been learned from a serious game; games can adapt to the player over time, which can make it hard to tell what was learned, and how quickly it was learned (Michael & Chen, 2006).

3.0 Solution Design

In this chapter we describe the Solution Design for the work described in Section 1.2, i.e., building a multi-platform mobile serious game and interviewing players to determine the effectiveness and enjoyableness of this game. First we identify the requirements for the application, as presented by the stakeholders. Next, we describe the technologies used to effectively create a multi-platform mobile serious game. After, we identify the features of the game and their functionality. Further, we describe both the design of the game play and the design of the game engine powering that game play. Last of all, we describe the interview process, highlighting the methodology and interview pool.

3.1 Requirements

In order to determine the platform and elements of the game, it is first important to determine the requirements of the serious game. During the development of this game with a Capstone team from The Ohio State University, there were two stakeholders which dictated requirements: a primary stakeholder in the Ohio Department of Health (ODH), and a secondary stakeholder working on the primary portion of the Apps for Asthma Management and Education (AAME) application, which focuses on allowing users to help monitor their asthma.

The primary stakeholder at the ODH had two simple requirements. First, the game

must allow the users to upload scores from the game to Facebook, in order to introduce a social aspect to the game that might encourage greater replayability. Second, the game must run on both the Android operating system and the iOS operating system. In order to target a large audience for our multi-platform release, we targeted on Android API Level 10 (Gingerbread 2.3.3) or higher and iOS version 5 or higher. This is because Android API levels 10 or higher cover 94.2% of the total Android population (Android Developer, 2013) at time of writing. While Apple does not release official version statistics for iOS, we estimate similar adoption rates. While we targeted Android API Level 10, effort was taken to allow the code to run on Android API Level 8 (Froyo 2.2) which boosts coverage to 98.3% of all Android devices.

The secondary stakeholder is the developer of the non-game portion of the Apps for Asthma Management application. This developer is therefore responsible for choosing the multi-platform framework. While multiple frameworks were covered, Titanium was chosen due to its ability to replicate the host operating system's native look and feel, and its greater responsiveness (Appcelerator Titanium, 2013).

3.2 System Design

3.2.1 Developing Multi-Platform Mobile Games

In order to match our clients multi-platform requirement while developing the application in the timeframe necessary, it was important to use a framework in order to allow us to develop for multiple platforms at once. This is achieved with Appcelerator

Titanium, which allows developers to deploy applications written using the Titanium framework to multiple operating systems at once while writing a minimal amount of code for each platform. In order to achieve this, applications written for the Titanium framework must be written entirely in Javascript. This is how Titanium achieves its cross platform compatibility: each operating system capable of running Titanium has a Javascript engine running in the background which executes the code written in Javascript. On Android developers choose between Mozilla's Rhino Javascript engine and Google's V8 engine, while on iOS Titanium uses WebKit's JavascriptCore interpreter.

While Titanium has the capability to create write-once applications for Android, iOS, and HTML 5 through the use of a Javascript engine backend, we restricted our target platforms to only iOS and Android, both in order to comply with the requirements set forth by the primary stakeholder and to allow for the use of a third-party game engine for Titanium named QuickTiGame2d (QuickTiGame2D, 2012). This game engine allows developers to create faster and more graphically intensive games. This is achieved due to the libraries usage of OpenGL ES, which allows for accelerated graphics on both Android and iOS. QuickTiGame2d is also optimized due to the language it is implemented in: Java on Android and Objective C on iOS. Since it runs code without first using a Javascript interpreter it allows us to create faster and more efficient code.

Although it is possible to stop using Titanium to draw the User Interface (UI) once QuickTiGame2D has been loaded and initialized, it is still possible to draw

Titanium UI elements on top of the QuickTiGame2D canvas. This approach is used several times when drawing the user interface in the game to allow both for quicker implementation of buttons and greater consistency of the User Experience (UX) throughout the application.

The use of third party game engines to improve performance is particularly important due to the wide range of phones targeted on this release. We aimed to deliver an enjoyable experience on low-end devices without sacrificing functionality. Low-end devices are considered to be closely based on the specifications of a HTC MyTouch 3G, which contains a 528 Mhz single core processor and 192 MB of RAM. In comparison, a high-end smartphone released at time of writing may have a Quad-core 1.6 Ghz processor with 2 GB of RAM.

3.2.2 Game Flow

The application flow diagram in Figure 1 is meant to show the various paths that can be taken to navigate through the application. Each square in the diagram is meant to represent a screen in the application, while diamonds are meant to represent important pieces of application logic.

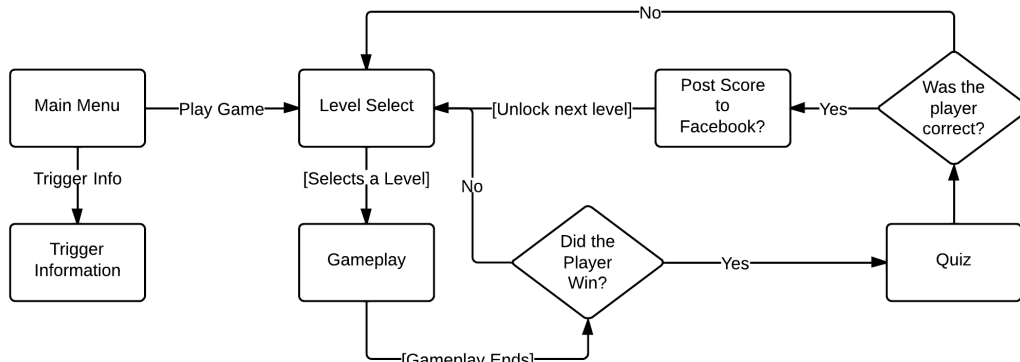


Figure 1: Application Flow Diagram

To aid in the understanding of the diagram we will describe the features of the application and reference the appropriate sections of the diagram.

Main Menu: The main menu of the application, viewable in Figure 7, is the first view users see after control is turned over to the main application. When control switches from the main AAME application to the game portion of the application, the phone orientation is changed from a portrait view to a horizontal view needed to play the game. While QuickTiGame2d is loaded into memory at the start of the main application, only at the main menu is it responsible for drawing items to the screen.

Trigger Information: Throughout the course of the game, players are tasked with defeating “triggers” for their asthma. The trigger information button allows for an easily accessible list of all the triggers that can be encountered in the game. Once a trigger is selected a detailed description of the trigger, viewable in Figure 9, is displayed which contains information that may be useful in day-to-day life, such as avoidance techniques.

Level Select: In order to allow replayability, the game contains 20 different levels. The level select, viewable in Figure 2, allows players to choose between levels. Each

level contains different triggers and different corresponding defenders, in order to maintain players interest by promoting variety and spread out the learning in the game, thus managing the players cognitive load (Greitzer, Kuchar, & Huston, 2007), a technique described in Section 2.2.1. When players are playing for the first time, only the first level is available, levels are unlocked in sequential order, introducing new enemy types to keep the player continuously engaged. For example, in Figure 2, the player has unlocked the first six levels, but must win at level 6 in order to unlock level 7.

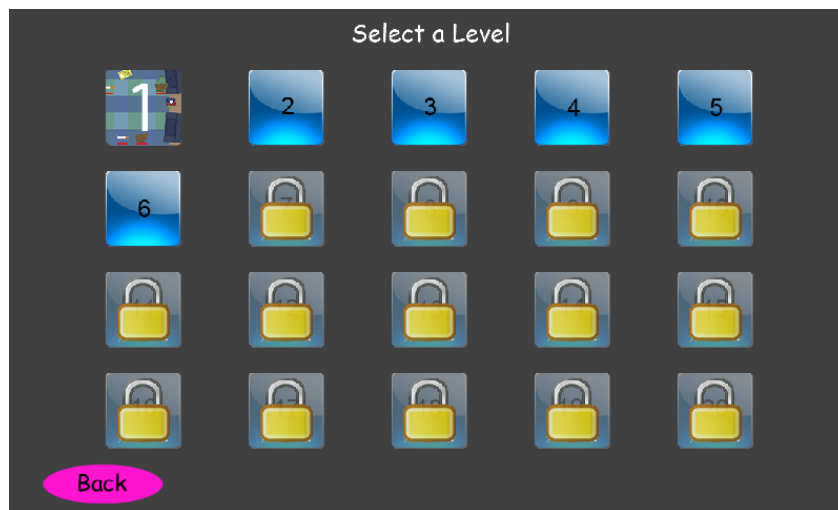


Figure 2: Screenshot for Level Selection

Quiz: Used both as an assessment and teaching tool, the quiz requires players to answer three questions related to triggers currently battled in the preceding level. Should the player successfully answer these questions, the next level will unlock and the player will be given the opportunity to post the score to Facebook.

Post Score to Facebook: Once the player has successfully completed a level, they will be given the opportunity to post the score to Facebook. This serves both as an

opportunity to raise awareness of the game, as well as a means to encourage replayability due to competition between friends.

3.2.3 Gameplay Description

The gameplay portion of a serious game is the most important part of the game: not only do players spend the majority of their time here, it is also expected to be both entertaining and educational. In order to make sure that these requirements are fulfilled, we look back to 2.1.2, which describes a method of classifying the “game” portion of serious games with Gameplay/Purpose/Scope. The purpose and scope of the game are well defined: the purpose is to teach players the basics of asthma to improve their ability to understand and handle asthma while the scope of the game is teenagers to young adults.

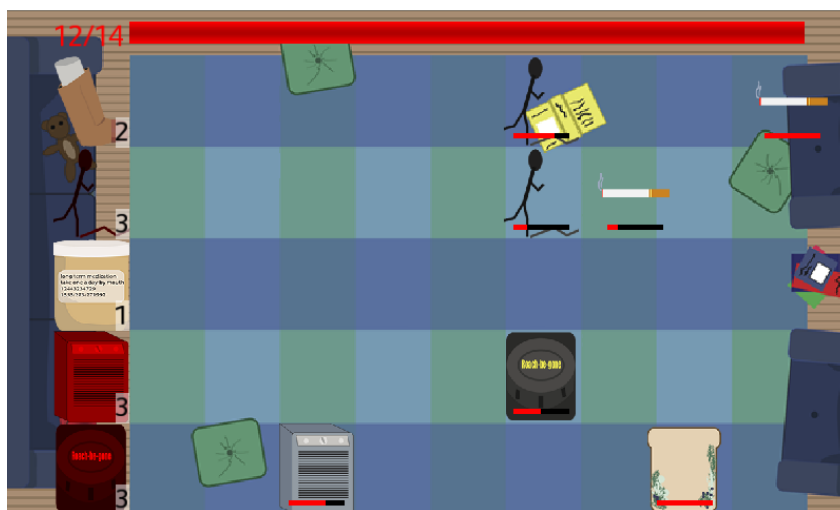


Figure 3: Screenshot for Gameplay

Classification of the gameplay is less well defined. Djaouti, Alvarez, and Jessel suggest defining gameplay with “Goals” and “Means” (Djaouti, Alvarez, & Jessel, 2011).

The gameplay screenshot in Figure 3 is meant to aid in understanding these goals and means, and is used in defining them. “Goals” are meant to indicate the goal of the player to win the game, and “Means” are meant to indicate the way that the player can achieve those goals.

Goals: Players must defeat all triggers coming from the right side of the screen before the triggers reach the left side of the screen. In Figure 3, example triggers advancing from right to left are the cigarettes in the first two rows, as well as the mold in row 5. Triggers which reach the left side of the screen disappear but damage the players health, represented by the red bar at the top of the screen. Should the players health decrease the red bar at the top of the screen reduces in size. Should this occur enough times for the bar to decrease completely, player loses the game and must retry the level.

Means: Players are able to remove triggers by defeating them with defenders. In Figure 3, example defenders are avoidance in the first two rows, a roach trap in the fourth row, and a dehumidifier in the last row. Certain triggers can be more effectively countered by their corresponding defenders. Both defenders and triggers have their own bars, representing health.

Players have the ability to move defenders onto the game space by dragging them from their symbols on the left side of the screen onto an unoccupied space on the game board. On the top left of the board is a population counter, which reads “12/14” in Figure 3. In Figure 3, the number on the right side of the counter, 12, represents the total population limit, while the number on the left side of the counter, 14, represents the

maximum population. Each of the defenders on the left side of the screen take up a certain amount of population, represented by the number next to them.

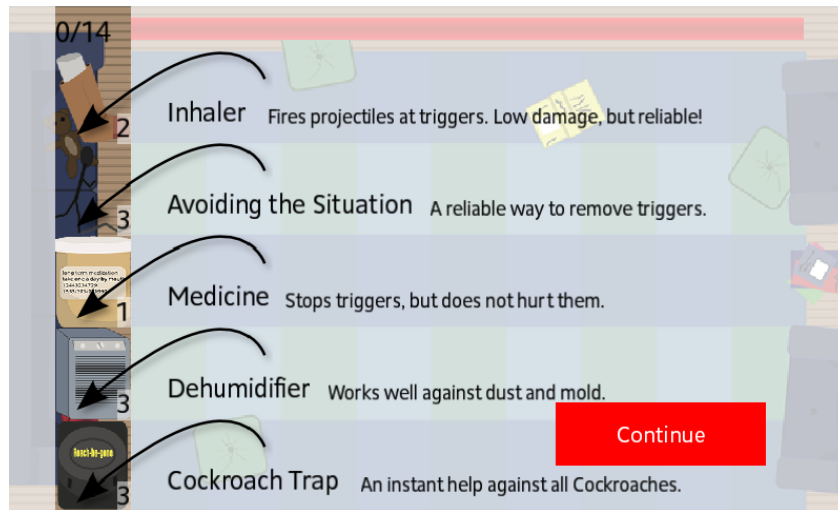


Figure 4: Screenshot for Defender Information View

In order to communicate the different types of triggers and defenders, players have the ability to view information about the defenders on their current level, as can be seen in Figure 4. This information helps players learn about the uses for these defenders, both in game and in the real world. Furthermore, players have the ability to access information about all triggers present in the game. Information about each trigger is automatically presented to the player before they encounter them in the game for the first time, but can also be access from the main menu or the pause menu of the game.

3.2.4 Game Engine

The class diagram in Figure 5 below represent the main classes used by the game in order to represent the objects in the gameworld.

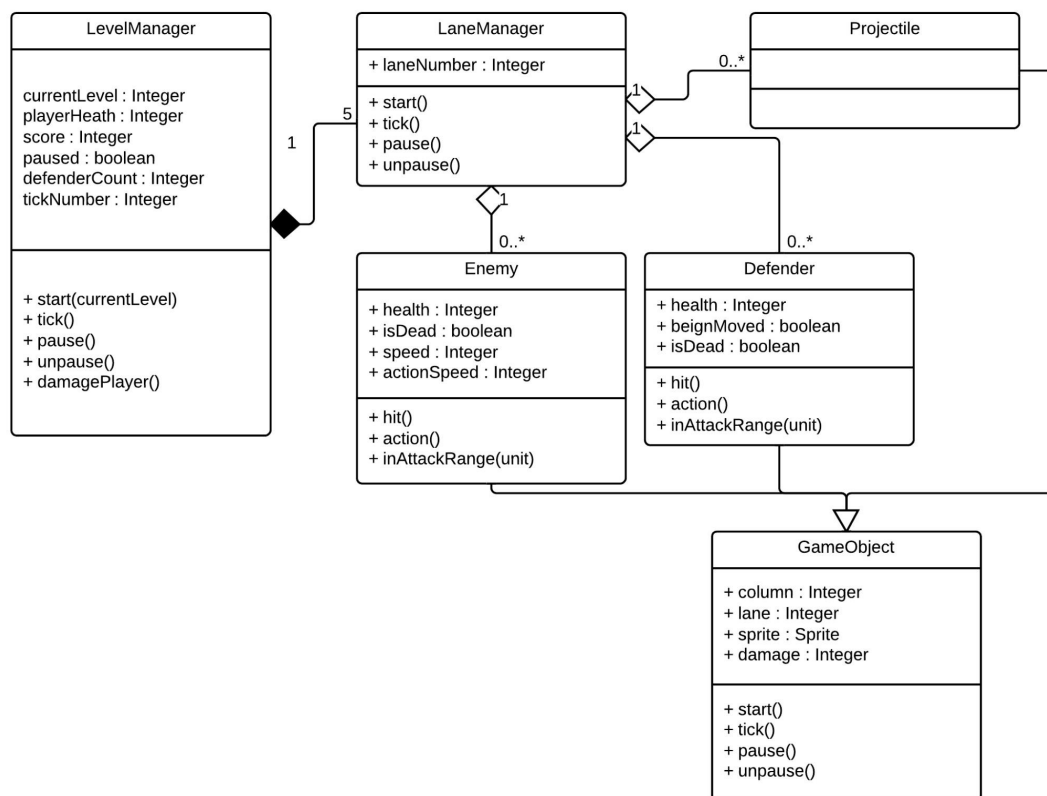


Figure 5: Class Diagram for main classes

In order to create and simulate the world, each object that exists in game must be represented in the code. The structure of in-game objects can be found in Figure 5, which demonstrates the hierarchical structure of the game. On the top of this structure is the LevelManager, which stores information specific to the level, such as the score, the players current health, and if the game is paused. Since the game is composed of 5 lanes (see Figure 3), the LevelManager contains 5 LaneManager, each responsible for simulating the content within their respective lanes. Each lane then contains Projectiles, Defenders, and Triggers, which are in turn responsible for simulating themselves.

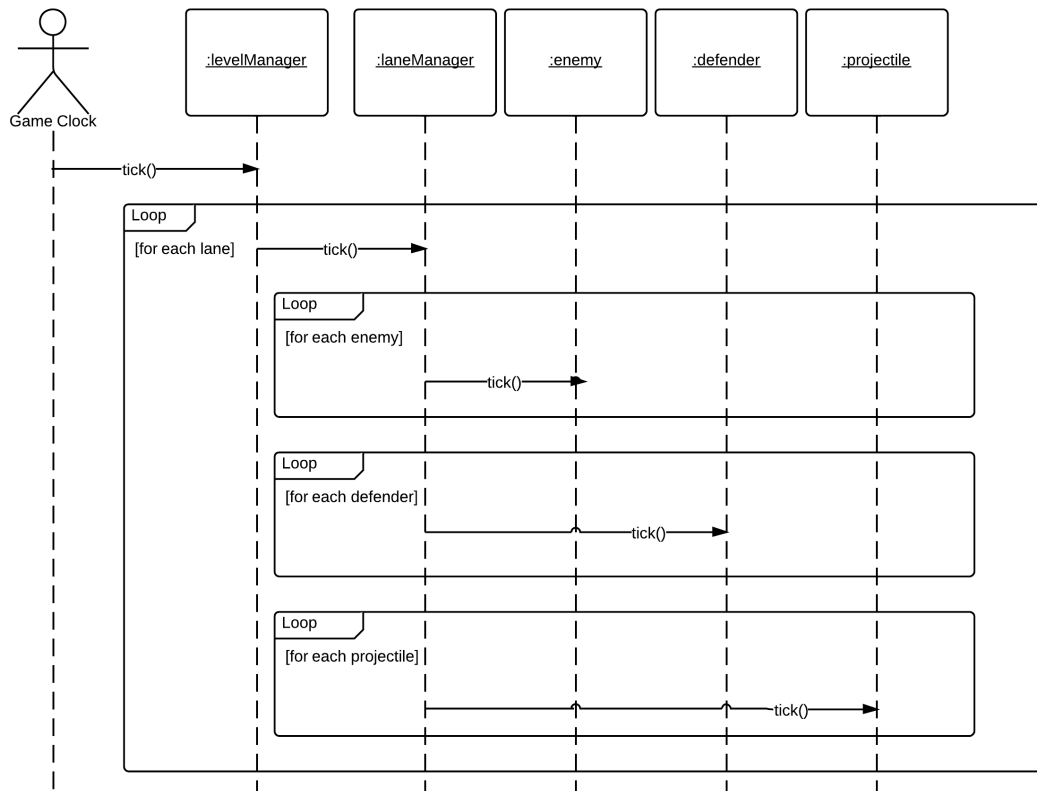


Figure 6: Sequence Diagram for Tick

Each item in the diagram has three important methods. First, the *start()* method, is responsible for setting up the object when it first appears on screen. While initial setup may be done during the construction of the objects on the class diagram, additional setup may be required when the objects are brought into play. Next, the *tick()* method, is responsible for simulating the game world. Every 100 ms the tick method in LevelManager is caused, which then cascades the ticks down to LaneManager, and finally, each of the objects in those lanes. The tick function for each of these objects is responsible for simulating the world. For example, a defender may choose to attack if a trigger is in range, or an attacker may choose to stop advancing if there is a defender

blocking him. Figure 6 is a sequence diagram which shows the way that a tick propagates down from the LevelManager. Lastly, the *pause()* method allows for the gameplay to stop at any time. This allows the user to bring up a pause menu, or allows for the display of an important message on the page.

Both the Defender class and Enemy class are important, since they relate directly to the problem domain. The Enemy class represents all the triggers that may cause asthma attacks, such as Mold, Cockroaches, and Pollen. The Defender class represent all objects and actions that can be used to combat the triggers to Asthma. For example, the defender named Dehumidifier is effective against the Mold enemy, since dehumidifiers can help prevent mold from growing. The game aims to teach these relationships to the players so that they may better understand and deal with asthma.

3.3 Interview Design

To test the effectiveness of the serious game developed, we interview a set of five people and record their responses. A population of convenience was used, with most interviewees majoring in the field of Computer Science and Engineering. For more information on the background of the users interviewed, please see Table 1. The interview process can be categorized into a set of 6 steps which determine the background of the subject, how much the subject learned about asthma from the game, and aspects of the game the subject liked and did not like.

Person Id	Owns Smartphone	Hrs/Week on Computer	Hrs/Week playing Games	Played Video Games Before?	Played Tower Defence Before?
1	Yes	12	0	Yes	Yes
2	Yes	40	4	Yes	Yes
3	No	60	15	Yes	Yes
4	Yes	40	1	Yes	No
5	Yes	60	0	No	No

Table 1: Background for Interview Subject

The first step in the interview process was finding out information on the background of the interviewee. Subjects are asked the information needed to fill out the first page of the questionnaire, as found in Appendix A, which covers background information unrelated to the game itself. The main purpose of this step is to get background on the user that may be used to correlate how much individuals improved to their background information.

The second step was to ask them a series of questions about asthma. This set of questions, found in Appendix B, contained two questions related to asthma but whose answers could not be found in the game, and three questions related to asthma but whose answers could be found in the game through the course of normal gameplay. Interviewees were asked this question before the game in order to get a baseline for their understanding of asthma. With the exception of question two, all questions ask the interviewee to select all correct answers that apply from a pool of both correct and incorrect answers. Points were added for each correct answer, and subtracted for each incorrect answer. Question two, which only had one correct answer, was worth one point if correct, and zero points if incorrect.

The third step was to present a copy of the game to the interviewee currently on the main menu and ask them to play the first two levels. While the interviewee was playing, wrote down observations of their actions, as well as notes on what may fix any problems they appeared to be having with the game. Before starting this step, I informed interviewees that I would not be able to help them with any questions they may have while playing the game, in order to more accurately simulate a user downloading the game for the first time without an interviewer present.

The fourth step asked the interviewee questions related to their experience with the game. The document used in this step, found in Appendix B, was filled out by the users without intervention. This section of the questionnaire was intended to gain information about what interviewees enjoyed about the game, and what elements interviewees believe could be improved about the game.

The fifth and sixth steps both ask the user to retake the questions originally asked for the first time in step two, which assess the interviewees understanding of asthma. This reassessment is to understand the amount of knowledge gained or loss after playing the game. The fifth step is taken immediately after step four, in order to assess how well playing improved knowledge of asthma while the knowledge gained was still in short term memory. The sixth step was taken one to two weeks later, depending on interviewee availability, and is meant to assess how well knowledge gained from the game was maintained in long term memory. In order to ensure that participants were not actively attempting to memorize answers for use a week later, interviewees were not told about

the sixth step until asked to perform it.

4.0 Results / Evaluation

In this chapter we describe the Results found when creating and refining the AAME game. First, we identify general trends observed during playtesting and the improvements made to the game in response to them. Next, we view how well playing a serious game helped interviewees, and how much the interviewees enjoyed the game. Last, we present the pros and cons of the technology used.

4.1 Observations during Interviews

During interviews interviewees were asked to play a two-level section of the game, without any guidance. This is to simulate the experience that a user might have when downloading and playing a game for the first time. While observing interviewees, I made several observations which can likely be applied to other games and software applications. Based on these observations, I made changes to the game in order to allow players to more easily learn material from the game. It's important to note that this set of interviews was conducted prior to the interviews overviewed in section 4.2.

First, interviewees only rarely decided to read the instructions which were displayed once the user selected the "Instructions" button on the main screen of the game. Often users believed that they would be able to learn the game while they started playing it, only to find that they were unable to understand the mechanics of the game. This issue was resolved by removing the menu button from the main screen of the game, as is viewable in Figure 7, and instead placing mandatory instructions at the beginning of the

first level, as is viewable in Figure 8.

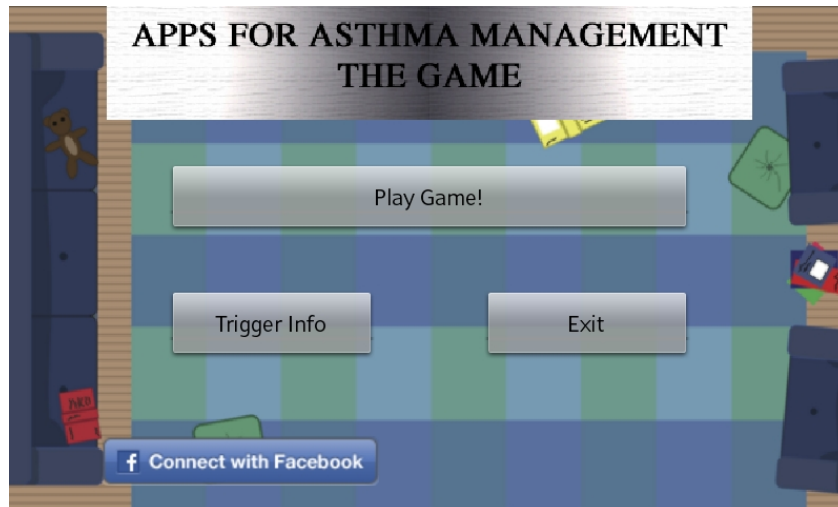


Figure 7: Screenshot for Main Menu

Second, interviewees that did open up the instructions tended to skim the instructions or skip large sections of the instructions. It appears that when players expect a gaming experience, they do not wish to understand the game before playing it, but instead learn the game while playing it. In order to ensure that players understand the basic rules of the game the longer instructions were condensed into three main points, as evident in Figure 8. Interviewees always read these instructions before clicking the “Continue” button. Based on feedback from interviewees, the color of the “Continue” changed to red from the default UI button to make it stand out on the busy game-screen. After doing so, players no longer experienced trouble finding the continue button.

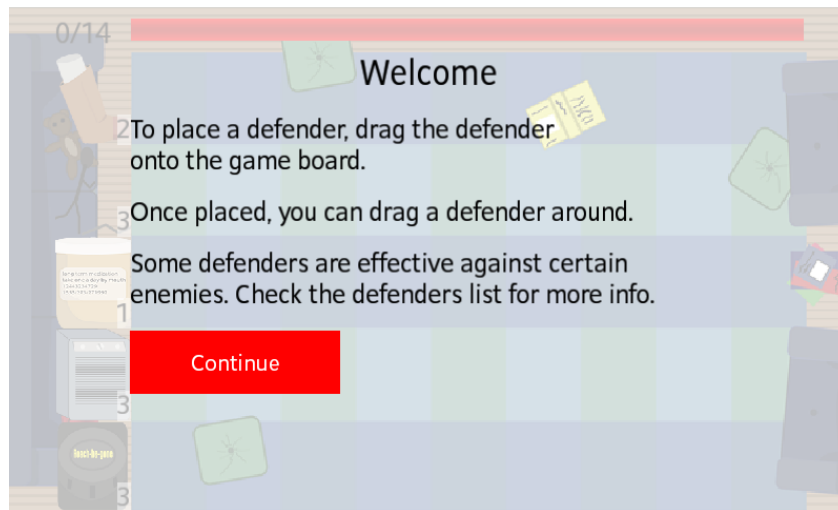


Figure 8: Screenshot for Instructions

_____ Third, interviewees often did not notice important events in game. In several playtests, testers did not notice health lost, and would be surprised when the game ended after all their health had drained from enemies reaching the left hand side of the screen. This was addressed by implementing a prompt on the first level, viewable in Figure 8, which comes up after the player loses health for the first time. By pointing out the presence of the health bar and correlating the loss of health with the event of an enemy crossing the screen, interviewees learned of the importance of the health bar and further learned of the goal of the game.

Last of all, when players were presented with information about triggers, they were not able to relate the information provided in the trigger's description with the triggers presence in the game. As with the first observation, this can most likely be attributed to several paragraphs of text that players did not wish to read. To resolve this issue, we added an icon of the described trigger, and added the defenders which the

trigger has weakness too, along with their corresponding icons, as can be seen in Figure 9. This allowed players to more easily get information about the triggers that they were defending against. We were able to observe that players more easily understood which defenders counter which triggers after implementing this change.



Figure 9: Screenshot for Trigger Descriptions

4.2 Improvement in Asthma Knowledge

In order to test how effective the game is at teaching about asthma, interviewees were asked questions about asthma three times: before the game, immediately after playing the game, and one to two weeks after playing the game. The procedure was used in order to get a baseline knowledge of asthma, measure how much the player understood asthma, and measure how well that knowledge was transferred into long-term memory.

It is important to note that the interviewee with Id 5 was not asked the last question: that question was added after that interview to better reflect the content that the game teaches. For results, please see Table 2.

<i>Person Id</i>	Before Playing the Game	After Playing the Game	1-2 Weeks After Playing the Game	Percent Improvement (Short Term)	Percent Improvement (Long Term)
1	7 / 16 (43%)	13 / 16 (81%)	12 / 16 (75%)	85%	71.4%
2	7 / 16 (43%)	13 / 16 (81%)	11 / 16 (62%)	85%	57.1%
3	6 / 16 (37%)	11 / 16 (68%)	11 / 16 (68%)	83%	83%
4	8 / 16 (50%)	11 / 16 (68%)	8 / 16 (50%)	37.5%	0%
5	6 / 11 (54%)	10 / 11 (90%)	8 / 11 (72%)	66%	33%
Overall	45.4%	77.6%	65.4%	71.3%	48.9%

Table 2: Results of Asthma Assessment

Table 2, which indicates the improvement each interviewee found after playing the game, indicates that interviewees showed on average a 71.3 percent improvement over their original scores. However, after a week or two, scores were reduced to an average of 48.9 percent. This decrease is to be expected, and it demonstrates the amount of information that interviewees were able to store in long-term memory.

What is most interesting about this reduction is an apparent correlation between the familiarity of the interviewee with the subject of serious games and the percent improvement over both the long-term and short-term: those who were not familiar with the genre of game, interviewees numbers 4 and 5 (according to Table 2) did not retain the knowledge gained from the game as well, according to Table 1.

In order to be an effective learning tool, the game must be enjoyable to encourage people to play it. While enjoyment is subjective, interviewees were asked to rate their level of enjoyment with the game, the results which can be observed in Table 3.

<i>Answer</i>	<i>Percentage</i>
Strongly Disagree	0 (0%)
Disagree	1 (20%)
Neutral	0 (0%)
Agree	3 (60%)
Strongly Agree	1 (20%)

Table 3: Results for the statement "I enjoyed the game portion of the application"

While 80% of interviewees indicated that they either Strongly Agree or Agree with the statement "I enjoyed the game portion of the application", each had recommendations on how to improve the game. For example, two of the five interviewees stated that the game's pace was too slow, and suggested speeding it up. Another interviewee suggested adding features, such as the ability to gauge the progress through the level.

4.3 About the Technology

While the technology used to build the game is discussed in Section 3.2.4, the techniques used to ensure that the game runs smoothly on low-end hardware are worth special mention. While the game operates based on a series of ticks, where each tick represents the simulation of the game world, an overly high tick-rate would cause a slowdown if the phone is unable to keep up with an ever increasing number of ticks. It is therefore important to keep the tick low enough to run without slowdown on the target low-end device.

With that goal, we chose a separation of 100 milliseconds between each tick. This runs without slowing the phone down, but movement of enemies does not appear smooth at this speed - 100 milliseconds between each tick correlates to 10 updates per second, so any enemy moving would appear to be moving forward at 10 frames per second, which does not appear as smooth movement to the viewer. We therefore used the *transform* method in QuickTiGame2d's Sprite objects, which allows properties, such as location, to change over time. Since QuickTiGame2D uses OpenGL and is compiled into Java Bytecode, we are able to use the *transform* method to smoothly move enemy pieces across the screen, and use the *tick* methods to control the starting and stop of movement. By leveraging the methods of the framework, we are able to achieve a game that works fluidly on a greater variety of devices.

5.0 Conclusion and Future Work

5.1 Conclusion

This thesis presents a game which allows users to learn about asthma in a way that aims to be entertaining and instructional, using a multi-platform framework in order to allow for a greater audience. In order to test its ability to teach as a serious game, interviews were conducted to get feedback on the game and gain knowledge on how the interviewees interact with the game. In interviewing subjects I found the importance of playtesting to find out player behavior, as by removing problem areas that players stumble on allow players to learn the game much quicker. I observed that serious games do effectively appear to teach, but that those familiar with the type of game learn better. Lastly, I found that technologies such as Titanium are able to effectively develop multi-platform mobile games, but that it is important to utilize the framework in order to ensure that the game runs smoothly on low-end hardware.

5.2 Future Work

Both the current state of the research and the current implementation of the game have areas in which additional work may take place. Interviewing additional subjects and finding information on the amount of knowledge gained would allow for more accurate conclusions, and the increased variety of backgrounds would allow for more conclusions

to be drawn. Additional interviews might also be conducted with the intent of comparing the results of learning through serious games to learning through more traditional methods that might be used to teach asthma, such as a verbal conversation and through written word.

Interviewees also gave feedback, indicating what they believe would make the game more fun. For example, two interviewees indicated that the game would be more fun if it was made more fast paced, and one interviewee indicated that the presence of sound would make the game more entertaining. Implementing these suggestions and further playtesting them to measure their effectiveness would allow for a more enjoyable and perhaps more educational game.

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Appendix A: Asthma Background Questions

The following form was filled out to gain information about an interviewees background.

<p>What is your level of education? Some high school / graduated high school / some college / graduated college</p> <p>If you are in or have graduated college, please list your degree(s):</p> <p>_____</p> <p>What is your age? _____</p> <p>Do you own a smartphone? Yes / No</p> <p>If yes, what do you use your smartphone for?</p> <table><tr><td>Making Calls</td><td>Sending Texts</td><td>Listening to music</td><td>Listening to podcasts</td></tr><tr><td>Playing Games</td><td>Checking Email</td><td>Instant Messaging</td><td>Navigation</td></tr><tr><td>Taking Pictures</td><td>Calendar</td><td>Watch Videos</td><td>Web</td></tr></table> <p>How many hours a week do you use a computer? _____</p> <p>How many hours per week do you play video games? _____</p> <p>Have you played Tower Defence Games before? Yes / No</p> <p>What type of games do you play, if any?</p> <table><tr><td>Tower Defence Games</td><td>First Person Games</td><td>Third Person Games</td></tr><tr><td>Strategy Games</td><td>Massively Multiplayer Games</td><td>Other (Please List)</td></tr></table> <p>Please list any other genres you play not on this list:</p> <p>_____</p> <p>Do you have asthma? Yes / No</p> <p>Do you know anyone with asthma? Yes / No</p> <p>If you have asthma, have you developed an Asthma Action Plan? Yes / No / Not Applicable</p>	Making Calls	Sending Texts	Listening to music	Listening to podcasts	Playing Games	Checking Email	Instant Messaging	Navigation	Taking Pictures	Calendar	Watch Videos	Web	Tower Defence Games	First Person Games	Third Person Games	Strategy Games	Massively Multiplayer Games	Other (Please List)
Making Calls	Sending Texts	Listening to music	Listening to podcasts															
Playing Games	Checking Email	Instant Messaging	Navigation															
Taking Pictures	Calendar	Watch Videos	Web															
Tower Defence Games	First Person Games	Third Person Games																
Strategy Games	Massively Multiplayer Games	Other (Please List)																

This form was filled out after interviewees completed the first two levels of the game.

Please select your level of agreement with the following statements:

I enjoyed the game portion of the application.

Strongly Disagree Disagree Neutral Agree Strongly Agree

I learned more about asthma from the game.

Strong Disagree Disagree Neutral Agree Strongly Agree

What did you enjoy about the game?

What didn't you enjoy about the game?

What could be improved to make the game more enjoyable?

What did you learn from the game?

What could the game do to teach you better?

How quickly would you give up playing the game?

Appendix B: Asthma Evaluation Questions

The following questions were used to evaluate interviewee's knowledge of asthma.

Circle symptoms of an asthma attack:

Non-stop Coughing	Throwing up	Chest Pain
Heartburn	Sweaty Face	Fever

The flu can make one more vulnerable to asthma attacks. True / False

What types of situations may induce asthma? (Circle all that apply)

Air Pollution	Cold Air	Tobacco Smoke
Pollen	Perfumes	Dusty Areas
Unusual smells	Cockroaches	Humid Air

Which of the following some common ways to aid in combating asthma?

Removing allergen causing bugs	Avoid Exercise
Sleep	Use a scarf
Usage of a dehumidifier	Stay at home
Use Medicine	Avoid using perfume