Design, Development, and Evaluation of Learning Games and an Interactive Science Lab
in a 3-D Online Virtual World to Support Middle School Science Education

A thesis presented to
the faculty of
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of the requirements for the degree
Master of Science

Bruce A. Bilyeu
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This thesis titled
Design, Development, and Evaluation of Learning Games and an Interactive Science Lab
in a 3-D Online Virtual World to Support Middle School Science Education

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ABSTRACT

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Video games have become a popular form of entertainment among today’s youth. They have also become a tool for educators to make learning more engaging. Previous work has shown that using learning games and interactive computer simulations in the classroom can provide many educational benefits. In this research, learning games and virtual science experiments were implemented in the 3-D virtual world of Second Life with the goal of enhancing classroom learning. This study focuses on the design, development, and evaluation of using multiple learning games and an Interactive Science Lab in middle school classrooms. The evaluation of efficacy of these learning modules was based on information gathered from pre-tests and post-tests from students in select middle school classrooms. The findings suggested that learning games and the Interactive Science Lab created in a 3-D virtual world were beneficial in enhancing students’ learning experience both as a standalone teaching tool and in aiding existing lesson plans.

Approved: _____________________________________________________________

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LIST OF ACRONYMS

API – Application Programming Interface
GK-12 – Graduate Teaching Fellows in K-12 Education
HTML – Hyper Text Markup Language
HTTP – Hypertext Transfer Protocol
HUD – Heads Up Display
IP – Internet Provider
LSL – Linden Scripting Language
MMOGs – Massively Multiplayer Online Games
NSF – National Science Foundation
PHP – Hypertext Preprocessor
SLurl – Second Life Uniform Resource Locator
STEAM – Science and Technology Enrichment for Appalachian Middle-schoolers
URL – Uniform Resource Locator
CHAPTER 1: INTRODUCTION

Educational game developers seek to create games that teachers can use to keep students motivated and interested to learn in the classroom. When it comes to video games for entertainment, many children have no problem finding motivation and interest to play them. Keeping children interested while learning can sometimes prove to be a challenge. This research attempts to bridge the gap between educational video games and recreational video games to increase student’s motivation and interest. Although educational games have been well researched in the past (Prensky, 2003; Rosas et al., 2003), this thesis will focus on creating and evaluating the efficacy of learning games for middle school students within Second Life, a 3-D online virtual world developed by Linden Lab (Linden Lab, 2009).

During this research two learning games and an Interactive Science Lab with three virtual experiments were developed in Second Life by the author. Another Second Life game, developed by a fellow graduate student, is analyzed in this research. Middle school science topics such as the scientific method, genetics, heredity, weather, and agents of erosion and deposition are covered in the learning modules. The modules were field tested in the classroom to evaluate their ability to teach classroom content using pre-tests and post-tests. This thesis will discuss the design techniques, results obtained, and the advantages and disadvantages of using a 3-D virtual world for teaching educational content.
STEAM GK-12 Project

This research was conducted through the Science and Technology Enrichment for Appalachian Middle-schoolers (STEAM) project (Franklin, Mayles, Liu, & Chelberg, 2007). The STEAM project was funded through a National Science Foundation (NSF) Graduate Teaching Fellows in K-12 Education (GK-12) grant. Goals of the STEAM project included broadening graduate education for engineering students at Ohio University and improving learning in science courses for middle school students at surrounding middle schools (Franklin et al., 2007). During this project, engineering graduate students worked with partner teachers from local middle school science classes to create digital curriculum usually in the form of video games. When designing the games, the graduate students and their partner teachers developed ideas for games to help with hard-to-teach concepts. Implementation was carried out by the graduate students while the teachers and other STEAM members provided feedback to help improve the game. The STEAM project members helped refine games throughout the development process. Partner teachers assisted the graduate students in aligning the games with Ohio’s academic standards for science content (Ohio Department of Education, 2002). The graduate students were required to spend ten hours a week in the classroom to assist in integrating the digital curriculum into the classroom and to participate in daily classroom activities.

The STEAM project used a variety of platforms to create learning games. STEAM graduate students conducted research using platforms such as Adobe Flash (Smearcheck, Franklin, Washington, & Peng, 2008), a game engine developed by the
STEAM graduate students called STEAMiE (Nykl et al., 2008), and the Second Life virtual world (Bilyeu, Mayles, Franklin, Liu, & Chelberg, 2007). STEAM graduate students chose from these different technologies to create a wide variety of games. Schools that participated in the STEAM project were sometimes limited to a particular platform because the technology in their schools could not meet the system requirements to run other platforms. Certain schools could not run any games with 3-D graphics. For them, Flash-based games were used instead. Other schools did not have enough Internet bandwidth to play games created in Second Life so the games developed on the STEAMiE engine were used instead.

**Thesis Organization**

Chapter 1 introduces the research project, provides pertinent background information, and outlines the topics covered in this thesis. Related work is covered in Chapter 2, including an introduction to virtual worlds and an outline of the virtual worlds that were considered for this research. Chapter 3 provides a complete overview of the project with an in-depth description of Second Life. Chapter 4 contains the details of the designs and implementations for the learning modules along with the methods used for deploying Second Life modules to the classroom. Chapter 5 presents the results for the modules evaluated in the classroom using pre-tests and post-tests. An analysis accompanies each set of results to provide insight into how effective the modules were in the classroom. Chapter 6 concludes the thesis by presenting the outcomes from the design techniques and from using Second Life learning games in the classroom. Chapter 6 also presents possible future work that can be conducted to further this research.
Author Contributions

The author designed and developed five of the six computer modules presented in this thesis within the virtual world of Second Life. These modules included Sugar and Water Solubility Experiment, Redi Experiment, Fruit Fly Genetics, Rafting Adventures, and Mystery School. Pre-tests and post-tests to evaluate the games were developed by the author with assistance from members of the STEAM project. The author implemented the Question Sets system for collecting pre-test and post-test data. Games were presented in the classroom and data was collected by the author with assistance from the partner teacher. Data was collected for the following modules: Sugar and Water Solubility Experiment, Fruit Fly Genetics, Rafting Adventures, and Mystery School. Data for the game Weather Challenge was obtained from other STEAM members. All data was statistically analyzed by the author. Conclusions were then drawn from the results by the author. Two publications pertaining to this research were written by the author: “Using Second Life to Create Educational Games for Middle School Science Students” (Bilyeu et al., 2007) and “Using Games Created in Second Life to Teach Middle School Science Content” (Bilyeu, Liu, Franklin, & Chelberg, 2008).
CHAPTER 2: RELATED WORK

The following sections cover related research that explores the benefits of using technology in classroom, including the use of educational video games. The end of the chapter gives an overview of online virtual worlds and their educational potential.

Learning with Technology

Many new forms of instruction have been developed using advancements in technology. Computers have caused educational videos to evolve into interactive videos and animations. Using emerging interactive media that allows students to visualize science in motion for education will only increase student’s ability to succeed (Dede, 2000). Using simulations within a 3-D world allows students to become encompassed by the visualization allowing them to move their character or camera angle to different positions to view the simulation.

Sometimes students comprehend content when initially learned but over time this content may not be retained. Emotional ties that are created while learning can provide lasting memories for students (Rieber, 2001). Using cutting-edge technology that excites students can help students create these emotional ties in order to enhance learned content with those memories.

Video Games for Learning

Research shows that an overwhelming number of children and teens play video games. A recent survey reported that “97% of teens ages 12-17 play computer, web, portable, or console games” (PEW Internet and American Life Project, 2008, p. 2). In the past decade, educational computer games have become more readily available for
students in the classroom through commercial software. Often children will have access to game consoles at home that are high-quality 3-D games for entertainment. Typically, educational games played in the classroom do not contain the same high-quality 3-D graphics that students play for entertainment. This divide in quality of commercial educational games and commercial entertainment games presents a gap which needs to be filled to help make educational games more appealing to students.

Video games for learning are hardly a replacement for conventional teaching; they are designed to be a complimentary instruction to be used with the typical curriculum. Previous research has found that educational video games can increase student’s achievements, motivation, and concentration in the classroom (Rosas et al., 2003). These benefits are compelling reasons for using educational video games, but they have negative aspects as well. Squire points out that “video games are not a silver bullet for education, in part because they will never appeal to all learners, but also because they alone will not likely change learners attitudes and values towards schooling” (Squire, 2005, p. 2). Even though it may be difficult to change a student’s negative attitude towards learning, an effective educational video game could make students forget that they are learning while playing the game. If the student is immersed in the game, they often abandon their attitude and instead focus on playing the game. This could potentially result in the student learning while simultaneously having fun.

One disadvantage to 3-D games is the learning curve can be steeper than a 2-D game. A virtual world can provide many options for interacting with the world and students may want to explore different aspects of the game. This process can take away
from the educational content provided within a 3-D game because students would initially focus on learning the game and may disregard the educational content (Bilyeu et al., 2008). However, while students are learning how to play the games, they still learn other valuable skills: “to take in information from many sources and make decisions quickly; to deduce a game’s rules from playing rather than being told; to create strategies for overcoming obstacles; to understand complex systems through experimentation” (Prensky, 2003, p. 2). The simplicity of 2-D Flash-based games can make them appear to be better suited for educational purposes. The key difference between 3-D and 2-D games though is how 3-D games immerse students into the game. This research aims to show that the immersion of a student into an educational game provides more educational benefits.

3-D Online Virtual Worlds

While many students may have played video games, there are a wide variety of genres in video games. One genre of games may not be appealing to every teenager. Using different genres and platforms to create educational games provides useful insight to find the best design techniques to apply to educational video games. This research focuses on using games created in a 3-D online virtual world to appeal to students. Previous research has shown that when students are able to explore a virtual world and interact with it they are more motivated and interested in the game (Tekaat-Davey, 2006). This section will provide an overview of 3-D online virtual worlds.
Overview

More than twenty percent of video game playing teenagers have played games that occur in an online virtual world or Massively Multiplayer Online Games (MMOGs) (PEW Internet and American Life Project, 2008). MMOGs consist of users logging into a persistent shared virtual space and controlling characters that they can use to interact with a large number of users. The game that is currently driving the increase in popularity of MMOGs is World of Warcraft, developed by Blizzard Entertainment (Blizzard Entertainment, 2009). World of Warcraft as of April 2008 held 62% of active MMOGs subscriptions with over 10,000,000 subscribers (Woodcock, 2008). MMOGs allow users to socially interact with other players in the game while using their customized character. Because characters in the games are human controlled characters, every time users log in they have a different experience.

Virtual World Platforms in Education

Features such as an entertaining online social environment and an easy to use interface are important aspects of online virtual worlds. During this research, a good user interface is especially important due to the novice users involved (Nielsen Norman Group, 2002). This research requires a 3-D virtual world that provides adequate development tools for creating games within the virtual world. Initial research for choosing a platform involved virtual worlds such as Multiverse, Active Worlds, Second Life, and game engines with online multiplayer capabilities such as Torque and Dark Basic. Second Life was chosen as the platform of choice because it excelled above the others especially with its comprehensive set of development tools.
Multiverse is a game development platform for creating virtual worlds that allows users to visit all virtual worlds developed with a single client application (Multiverse Overview, 2009). After being founded in 2004, Multiverse remained in beta until August of 2007 (Multiverse Overview, 2009). During the evaluation of Multiverse by STEAM graduate fellows, the feature set was limited when compared to other platforms at the time of choosing a development platform.

Active Worlds is a multi-user virtual environment that was originally designed for 3-D chat in a virtual world (Active worlds. 2009). Active Worlds has been used in previous research such as the National Science Foundation funded projects that developed Quest Atlantis (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005) and River City (Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004). Quest Atlantis contains various educational tasks relying heavily on storylines and social interaction for understanding 9 to 14 year old student’s learning and cognition processes (Barab et al., 2005). River City was developed at Harvard University for teaching middle school science students about scientific inquiry (Dede et al., 2004). The game takes place in a 19th century community where students must work in research teams to diagnose problems that cause the residents to become ill (Dede et al., 2004). Although Active Worlds was already established as a useful educational tool, Second Life was more appealing for this research for creating games because of a more interactive world and better development tools.

Using a game engine such as Torque (Kanalakis, 2008) or Dark Basic (The Game Creators, 2009) can provide the most flexibility for development but both platforms are catered towards first person shooters and racing games. In order to use these engines for
this research, they would require extra development time to customize the games. Another major drawback from game engines is the amount of work that 3-D modeling would require. There was not a graphic designer provided during the STEAM project to handle this task so all models would need to be developed by the author or purchased.

Second Life is an online virtual world that launched in 2003 where users can explore, socialize with other users, and create virtual objects (Rymaszewski, James Au, Wallace, & Winters, 2007). The virtual world consists of content developed through development tools built into the Second Life client. The client provides an in-game 3-D modeler and scripting language for developing interactive objects. Second Life does not have a traditional objective to the game and is primarily used for socializing and developing creative user content.

Second Life became the development platform of choice for this research because developers can create custom 3-D games rather quickly within an already feature rich virtual world. Quick object creation through the in-game 3-D modeler and the Linden Scripting Language provide tools to simplify and accelerate the game development process. When compared to the other virtual worlds analyzed in this research, Second Life had the easiest to use development tools for creating games because they were easily accessible in-world and designed for novice users.
CHAPTER 3: PROJECT OVERVIEW

This section will provide more detailed descriptions of the project, including an overview of Second Life. The overview of Second Life will outline the main features of Second Life and how they affect this project.

Research Process

An effective educational game should enhance the learning and retention process while providing an entertaining experience for the learners. The following steps were followed during this research in order to create and disseminate effective learning games:

1) Develop engaging games that adhere to academic content standards (Ohio Department of Education, 2002)

2) Evaluate the effectiveness of the games in the classroom

3) Prepare games to be released to public for other educators to use

Classroom Environment

Classes that participated in this research ranged from 15 to 25 students with class periods that lasted approximately 45 minutes each. Each student in the class was logged into Second Life from the same classroom. In the United States many schools have a T1 connection (SETDA: State Educational Technology Directors Association, 2008). At School A where the bulk of the research was conducted, grades K-12 are located in the same building and share three T1 lines. This is plenty of bandwidth for one user but the school shares this bandwidth among every user in the school. Because this connection is shared for the entire school, not as many applications that require a lot of bandwidth are able to take advantage of the fast connection simultaneously.
Second Life

Second Life is an online virtual world where users can create scriptable objects to interact with. Upon logging into Second Life, a user is in control of a character (avatar) which allows each user to interact with the world. Each user can customize his or her avatar’s appearance by changing the avatar’s clothing, hair, physique, etc.. Each avatar can navigate the world by walking, flying, or teleporting. Second Life has its own economy system using Linden dollars that convert to U.S. dollars (Rymaszewski et al., 2007). The economy in Second Life is driven by user-created content. Users can upload their own textures, sounds, and animations for 10 Lindens, each of which translates to approximately 3.86 cents.

Users can own their own land within the Second Life virtual world, which allows them to build whatever they want. Owning property in Second Life requires an initial purchase of the land and paying a monthly maintenance fee (Rymaszewski et al., 2007). User-created content makes up the virtual world of Second Life. Second Life is divided into separate islands that users can teleport between. The islands are divided into separate grids for dividing teen and adult users.

Users are able to chat with others using text or voice chat. When chatting through text, users can instant message privately with other users, publicly within twenty meters, or shout across the entire island (Rymaszewski et al., 2007).

Research Considerations

Using an online 3-D virtual world in the classroom presented various challenges during the course of this research. Unlike simple Flash-based games that are accessed
through a web browser, Second Life uses a client application to log into servers that host the virtual world. This section will outline issues that needed to be considered when using Second Life in this research.

Within the STEAM project, special provisions were needed to keep the students isolated from other users within Second Life. An island that is isolated from the rest of Second Life was purchased through the grant to keep students separated from the outside world. Special user accounts were needed to prevent students from communicating with other users in other parts of Second Life and to prevent them from teleporting to other islands. These precautions were a necessary requirement in this research due to the fact that making other users and islands available to students could expose them to inappropriate content.

Deploying games within Second Life to a lab environment only requires changes to the virtual world of Second Life instead of installing software to multiple computers in a lab. Any change in Second Life is made for all users that log into Second Life because all games are developed on the Second Life servers. This feature was especially useful when field testing games in a computer lab. On a few occasions, bug fixes were implemented in between or during class periods. Second Life can be executed from a shared network drive. Any changes that are required for the Second Life client can be easily updated in one location for the entire lab. These types of updates could not be deployed as quickly in game engines that run from a local installation or do not use a client and server approach.
In order to fulfill the research objective of distributing the games to the public, the learning games must be packaged into a single object, which users must unpack. Distributing the Second Life games to other educators is not as easy as allowing them to download the game from a website. Once the games have been packaged into a single object, educators must use a Second Life account to teleport to the location of the object to receive a copy of the game and then must set the game up on their own virtual island. Second Life provides links to locations via Second Life Uniform Resource Locators (SLurl) that allow users to easily teleport to different places within Second Life.

**System Requirements**

Hardware requirements to run the Second Life client present another problem for educators. The hardware requirements are modest for a 3-D video game but computers within schools can be outdated. The minimum hardware requirements for a Windows XP-based computer are (Second Life, 2009, para. 1):

- Processor: 800 MHz Pentium III or Athlon
- Memory: 512 MB of RAM
- Graphics:
  - NVIDIA GeForce 2, GeForce 4 MX or better
  - Or ATI Radeon 8500, 9250 or better
  - Or Intel 945 Chipset

Second Life also has network requirements. The client requires the following network ports to be unlocked: 443/TCP, 12043/TCP, 12035/UDP, 12036/UDP, and 13000-13050/UDP (Second Life Wiki, 2009a). Second Life recommends either a DSL or
cable internet connection in order to run smoothly without network lag affecting the
game (Second Life, 2009).

Scripting and Object Creation

Objects can be created either through importing ones created from 3-D modeling
software or by using the editor within Second Life. All objects used in developing the
games in this research were created using the in-world object editor due to the short
development time and simple interface the editor provides for creating objects. The
process of creating an object or making one appear in Second Life is referred to as
rezzing (Second Life Wiki, 2009c). When using the in-world editor, users can edit the
properties of simple 3-D shapes (primitives) to change the shape, rotation, texture, etc..
These primitives can then be linked together to form objects. Each primitive or object can
contain scripts that allow the object to interact with the world. Figure 1 shows Second
Life’s object modeler and script editor. Because Second Life user generated content is
created in the same world, many of the objects and scripts are shared among the users.
This speeds up the development process when you can find an existing object to use
instead of having to create a new one yourself.

Scripts within Second Life are created with Second Life’s Linden Scripting
Language (LSL). The syntax of LSL was designed to be similar to popular programming
languages such as C and Java. Scripting within Second Life is easy to learn and many
users have their first programming experience in Second Life. LSL is a state based
language which is driven on events. Multiple scripts can be placed into each object or
primitive to provide functionality to objects. Second Life provided the functionality for
developers to program using Mono but this feature was added to Second Life after the games in this research were developed (Second Life Wiki, 2009b).

Figure 1. In-game Object and Script Editor Screenshot (Captured by Author in Second Life)
CHAPTER 4: LEARNING GAME DEVELOPMENT

During this research, the games were being actively developed and changed according to the student’s reactions from playing the games in the classroom. Observations and feedback acquired from deploying the first games in the classroom provided useful insight that was used when developing other games for this research. This chapter will present these design considerations for developing educational games in Second Life as well as a description of the learning games and common features that exist across multiple games.

Design Considerations

Some of the games created were designed initially to be purely educational and are more of a simulation. The experiments within the Interactive Science Lab are a simulation but each contains a mini-game to make the experiment more fun. The main disadvantage to simulation-based games is they lose their replay value easily because the simulations stay basically the same across multiple iterations of playing. Therefore all mini-games within the Interactive Science Lab employ a scoring system to enhance the replay value. With a competitive high score system students will have a reason to replay the simulation even if the outcome of the experiment does not vary much.

Using a virtual world as the development platform heavily influenced the design of the educational games in this research. The 3-D world in Second Life allows developers to create games that include exploring, racing, or flying. Taking advantage of the best features of Second Life helps shorten development time. For instance, a maze type game would be easier to develop in Second Life instead of creating it in a 2-D
engine such as flash. Games created within this research take advantage of the 3-D space that Second Life provides by allowing users to explore their surroundings while playing the games.

When developing games in any game engine the developer is limited by the programming language and application programming interface (API) that the engine provides. Second Life’s scripting language is limited when compared to typical 3-D game engines. As more programming experience was acquired with LSL, the language became more familiar and solutions to difficult tasks could be developed easier. For example, scripts are limited in memory but spreading out functions among multiple scripts fixed that problem. Being more familiar with LSL shortened the development times and this allowed more features to be implemented in new games.

To effectively deliver educational content within a video game in an open world such as Second Life distractions must be kept at a minimum. Students can interact with many objects in the virtual world as well as click menu buttons to explore all the features that Second Life provides. Because Second Life is a virtual world, students are distracted by features such as flying to explore the world and the ability to chat with others. Preventive methods were added to the educational games to deter these distractions. In some games, students are required to remain seated throughout the game to prevent them from flying and exploring the island. When students are seated on an object such as a chair in a lab or vehicle for a race, playing the game becomes much simpler because students no longer have to ask where to go next.
Chat loggers were created to prevent chatting. Students were forewarned about the loggers and told that chatting was only permitted if their conversation applied to the game. This rule was broken but the chatting never got out of control and disciplinary action was never needed. Using the chatting feature for asking questions turned out to be a great feature that was not planned when developing lesson plans. Students were allowed to announce questions to everyone in the class in the virtual world and other students would help their classmate by answering their question.

A common technique used in educational games is to provide a reward or to allow students to advance in a game when they correctly answer educational questions related to the game. This technique is used within the Mystery School game to promote learning. When using in game questions students have a tendency to game the system by guessing the correct answers to questions until they are correct in order to advance in the game (Baker, Corbett, Koedinger, & Wagner, 2004). Even though Mystery School requires students to answer questions to advance in the game, their answers are not evaluated until the end of the game. Therefore if the students guess their answers, they will need to start the game over in order to receive their reward.

Common Features

In order to stay focused on a task, students must be given clear and accurate instructions. For this reason all games make use of a Heads Up Display (HUD), which is used for displaying instructions, educational content, and control aspects of the games. The HUD, as shown in Figure 2, provides an easy to use interface for students to refer to
when playing the game and to prevent the confusion that a complex application as Second Life can present to middle school students.

*Figure 2.* Heads Up Display Screenshot (Captured from Interactive Science Lab by Author in Second Life)

In the games developed by the researcher, the HUD was designed to be simple for the students to use by only having a small amount of buttons and a consistent look and feel among every game. This HUD contains three buttons that were statically built into the HUD: a continue button, a reset button, and a show/hide information for hiding the
text area. Other buttons that were specific to games were always displayed within the textual area of the HUD.

Initially the HUD was designed to display static text using uploaded textures. Eventually the HUD was upgraded for most of the games to be able to display dynamic text. When using textures containing text, if a change needed to be made then the texture would have to be uploaded into Second Life again and then placed in the HUD. The dynamic text, which was added using a shared library called XyText (LSL Wiki, 2007), allows the game instructions and information to be changed within a script of the HUD. The dynamic text helps improve load times of the text because once the texture for each letter has been cached no more textures will need to be loaded. When large changes were made to the HUD such as the dynamic text, the code was applied to other games in the research project.

Another use of the HUD was for asking pre-test and post-test questions. This method allowed for quick and easy data collection. The use of dynamic text in the HUD led to the use of dynamic questions for the pre-test and post-test using the Question Sets system as seen in Figure 3. The Question Sets system consists of an external PostgreSQL database outside of Second Life with a web interface created using HTML (Hyper Text Markup Language), PHP (Hypertext Preprocessor), and JavaScript. The web interface, as seen in Figure 4, allows the developers and teachers to be able to change questions and monitor the results submitted during the game in real-time. Games acquire questions and submit results by making HTTP (hypertext transfer protocol) requests and parsing the text returned in the game. Multiple question sets can be created using the web interface.
The sets are interchangeable between games by changing the HTTP request to retrieve the questions. Once results have been submitted to the database a summary of the results can be downloaded in an Excel document filtered by question set, IP (Internet Provider) address, date, question number, or student identifier.

Figure 3. Dynamic Pre-test Questions Displayed on HUD Screenshot (Captured from Mystery School by Author in Second Life)
Another external database is used in a portion of the game’s high score system. This database is used for storing student’s scores which are submitted to the database after they complete each game. A web interface is used for modifying records on the scoreboard and to view the scores in real-time. The high score system provides Second Life an effortless method for storing scores externally so they are more manageable.

**Figure 4.** Question Sets Web Interface Screenshot (Captured by Author)
Learning Game Descriptions

This thesis presents a total of six Second Life learning modules developed for middle school science classes. Table 1 presents an overview of the modules by outlining the relevant academic standards, science content, type of game, and Uniform Resource Locators (URL) that provide more information about each module. The YouTube URL presents an informational video that was produced by the author showing the key features of the modules using gameplay footage. A wiki is a web application that allows users to create and edit websites within a web browser. The wiki URL that is provided in Table 1 links to a webpage that outlines the features in the modules. Three of the modules are science experiments that are part of an Interactive Science Lab: Sugar and Water Solubility Experiment, Redi Experiment, and Fruit Fly Genetics. The other modules include Rafting Adventures, Mystery School, and Weather Challenge. All modules developed in this research have been deployed to a public island on the teen grid at the SLurl of http://slurl.com/secondlife/Ohio%20Teen/128/128/16.
## Overview of Modules Presented in Thesis

<table>
<thead>
<tr>
<th>Game</th>
<th>Relevant Academic Standards</th>
<th>Content</th>
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<th>Wiki URL</th>
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<td>Scientific Method</td>
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<td>Observations and inferences</td>
<td>Adventure to solve a mystery using observations and inferences</td>
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During this research many objects had to be developed in Second Life for each learning module. Table 2 documents the amount of content that exists in each learning module developed by the author. The value for the lines of code does not include code that is repeated in multiple scripts in different objects. Each total for the games in the table include amounts for the HUD which consists of 81 primitives that all contain scripts except for four of the primitives. The lines of code in the HUD vary between games but approximately 1275 lines of code are common to the HUD in all games.

Table 2

Outline of Content Developed in Second Life Modules by Author

<table>
<thead>
<tr>
<th>Learning Module</th>
<th>Number of Objects/Primitives</th>
<th>Number of Scripted Objects/Primitives</th>
<th>Lines of Code</th>
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<td>6/14</td>
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<td>4112</td>
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<td>70/366</td>
<td>70/182</td>
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<tr>
<td>Mystery School</td>
<td>82/3382</td>
<td>25/132</td>
<td>5519</td>
</tr>
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Interactive Science Lab

The Interactive Science Lab was created to provide a virtual lab where students are able to easily perform fun science experiments quickly. Most experiments within the lab were designed to teach the fundamentals of the scientific method along with the content within the experiment. The Interactive Science Lab provides users with an opportunity to perform experiments that normally cannot be experienced in a classroom.
(Franklin, Chelberg, & Liu, 2009). The lab contains safety equipment for students to interact with such as a shower and eye wash station and safety goggles that they can wear. When entering the lab, students can sit down at a lab desk by clicking on it. Then they can acquire a HUD by clicking on the test tubes located on the corner of their desk. The user will then receive the HUD object and a virtual notecard explaining how to attach the HUD. A virtual notecard in Second Life is an object that is used for displaying and editing text. Once the HUD is attached it prompts the students to type their name through chat for the high score system as displayed in Figure 5. The HUD will then display the main menu where students can select one of three science experiments to conduct.
Sugar and Water Solubility Experiment

The first module developed for the Interactive Science lab by the author was the Sugar and Water Solubility Experiment. This experiment was designed solely for teaching the scientific method by focusing on topics such as variables, controls, and the steps of the scientific method. The experiment consists of dissolving sugar in three cups of water at different temperatures. In the experiment students will discover which water temperature dissolves sugar the fastest. During the experiment, each step of the scientific method as it applies to this experiment is stated on the HUD. The experiment also makes use of a high score system that is based on how well the students perform the experiment according to the rules of the scientific method.
When the Sugar Water Solubility Experiment is selected from the main menu, students will start their pre-test that consists of questions obtained through the Question Sets system. The lab materials that the students will use are automatically set up for each step of the experiment. During the procedure step of the scientific method, students are able to interact with the materials. Students start performing the experiment by left-clicking the mouse on the sugar bag to drag it to the right side of a measuring cup and then release to pour the sugar as seen in Figure 6. The location of the sugar bag compared to the measuring cup when pouring dictates how much sugar is dispensed into the cup. This variation in the amount of sugar is used to teach students about variables and control in the experiment. The more consistent the students are at pouring the same amount of sugar then the better their score will be in the game. After pouring, students have the option to empty out their measuring cup by clicking on it so they can pour a different amount of sugar. Once the desired amount of sugar is in the measuring cup, the sugar can be placed in the water cup to dissolve by clicking continue on the HUD. The water cup will then glow to indicate the sugar is dissolving and the amount of time that has elapsed appears above the cup. Students must then click the water cup when the sugar is done dissolving to time it. This process must be completed for all three cups, which contain cold, room-temperature, and warm water. After students are finished with the experiment they are prompted to complete the post-test and are given their score.
The Sugar and Water Solubility Experiment went through many design changes because it was the first module that was developed. Initially the experiment did not use a HUD and instead all information was conveyed through notecards and pop-up menus. Feedback from the STEAM project led to adding a HUD to the module which drastically improved the usability and educational value of the game. The HUD allows the instructions and pertinent educational content to be displayed during each step of the experiment.

*Redi Experiment*

The next experiment developed for the Interactive Science Lab was the Redi Experiment. This experiment was developed in order to teach the scientific method along
with the historical science experiment that Francesco Redi used to disprove spontaneous generation. Because this experiment deals with rotting meat, it is a great example of an experiment that students typically could never perform in the classroom.

During the experiment, each step of the scientific method as it applies to the experiment is outlined in the HUD. Users are initially given three jars containing raw meat. One jar is left open. Another jar is covered with netting. The third is kept closed. The experiment begins by outlining Francesco Redi’s purpose and hypothesis. Users are then given a closed jar of flies which can be opened by clicking on the jar to release the flies. Students then view the flies being attracted to the jar covered with netting and the one left open. As students continue the experiment, they view the maggots forming on the netting and on the meat in the open jar.

Students are then prompted to play a game to help clean up the experiment by picking up the maggots. The faster students pick up the maggots the better their score will be. When the game starts, the camera is automatically positioned above the maggots as seen in Figure 7. Students must left-click on the moving maggots in order to make them disappear. Their scores are then displayed and submitted to the high score system. This integrated game was added to increase replay value in the experiment and help make the experiment more fun.
Figure 7. Redi Experiment Mini-game Screenshot (Captured by Author in Second Life)

_Fruit Fly Genetics_

The last experiment created for the Interactive Science Lab is the Fruit Fly Genetics experiment. This experiment focuses on teaching students about heredity and punnett squares without as much focus on the scientific method. Students receive an accompanying worksheet to work on during this experiment which is located in Appendix A.

Students start the experiment by viewing vocabulary terms which they must learn in order to understand parts of the game. These terms are displayed using the HUD and are provided with the worksheet. After the user clicks continue, they are presented with the opportunity to choose colors to use for the traits of the fruit flies for their body and eyes. Users are then shown the two different wing types in the game through the HUD.
The dominant wing type is wild and the recessive trait is vestigial. Users are given two small jars containing heterozygous fruit flies that must be combined to breed the flies. More fruit flies are produced and the user is prompted to put the flies to sleep using the jar of ether by clicking continue on the HUD. Students must then fill in the first set of punnett squares on their worksheet in order to make predictions about the offspring produced. The offspring are dynamically computed based on the probability of the parents producing particular offspring according to the values of their punnett square.

After the fruit flies are put to sleep, the user is prompted to inspect the fruit flies through the use of a dividing tray. During this process, the camera view is placed above the dividing tray as seen in Figure 8. Users then count the amount of flies with the dominant and recessive traits for each of the variable characteristics of the fruit flies by clicking on the plus or minus signs on the HUD. The student’s ability to quickly and accurately count the phenotypes of the fruit flies is used for determining their score for the experiment. After counting the traits and clicking continue, users are shown a graph of the actual results which they can use to compare to the predicted results calculated on their worksheet. After completing this for the body color, eye color, and wing type, users have the opportunity to breed another generation of fruit flies based on parents that the user chooses.
Rafting Adventures

Rafting Adventures is a virtual outdoor game developed for demonstrating agents of erosion and deposition (see Figure 9). Users ride a raft down a mountain side to the ocean viewing seven different animations of erosion or deposition as seen in Figure 10. This game provides students with a virtual field trip that students would never be able to take in real life. Showing students agents of erosion and deposition in a 3-D world provides an entertaining demonstration that students can understand better than reading from a textbook. Rafting Adventures was the third module created by the author.
Figure 9. Rafting Adventures Course Screenshot (Captured by Author in Second Life)

Figure 10. User Riding Raft in Rafting Adventures Screenshot (Captured by Author in Second Life)
Rafting Adventures starts when users obtain a HUD at the base of the mountain. The HUD first prompts users to take the pre-test which is connected to the Question Sets database system. Users then begin playing the game by teleporting to the top of the mountain where they will sit on a raft to begin their adventure. All of the seven checkpoints in the game are activated when the user’s raft collides with an invisible object on the path of the stream. After the collision is detected, the game automatically directs the user’s view towards the location of the current animation and the HUD displays information related to the checkpoint. Once the user clicks continue, the animation begins. Upon completion of the animation, the HUD will explain what was seen.

Gates were implemented to prevent students from entering the same section of the course where animations occur. After a user passes through the invisible gate, a trigger will cause the gate to be activated to prevent anyone from entering the checkpoint that the user is currently in. Once the user is done for that checkpoint and continues on to trigger the next gate, the previous gate will become invisible again to allow other users to pass through.

Within the game, students are explained during the checkpoints that some of the animations are not shown according to scale and that the process occurs over a long period of time.

Checkpoints include animations of the following types:

- Glacier eroding a mountainside (see Figure 11)
- U-shaped valley being formed by erosion of a V-shaped valley from a glacier
- Differential weathering of a stream bed with bedload
- How an oxbow lake is formed out of a meandering river
- Rising waters on a floodplain
- Erosion that creates a cut bank and deposition that creates a point bar
- Sea cave formed from the crashing of waves along the shore

After completing each checkpoint, users will finish the course in the ocean. They will be prompted to take the post-test. After completing the post-test, they are free to move their raft around the island.

Figure 11. Glacier Animation in Rafting Adventures Screenshot (Captured by Author in Second Life)
In order to create a releasable object for Rafting Adventures, extra development time was required because the land must be shaped into a mountain. The course in Rafting Adventures can be created through the click of a button. Once the button is clicked, small objects are rezzed to adjust the ground level of the course through scripts. After the land is formed into the correct shape of the mountain, the main rezzing object creates the pieces of the game such as the different landforms and the stream that runs down the mountain. Rafting Adventures also has a button for clearing the entire game to return the land to a flat plane.

Rafting Adventures went through many changes in order to make the game usable in a classroom environment. A major disadvantage of Rafting Adventures is the game only allows one user to view any animation at a time. Therefore, only a total of eight users can be on the course at any time. Due to this limitation, two courses needed to be used when playing the game in the classroom. Having two courses worked but was not ideal when managing a class of students on two mountains in Second Life.

Another problem that occurred, when using the game in the classroom, is students found a way to break the checkpoints allowing two students to be on a checkpoint at the same time. They accomplished this by entering the first checkpoint at the same time. To fix this problem, an invisible border was placed around the area where users obtain their raft. Students could only access this enclosed area by riding a chair-lift that permits only one student to be in the area at a time. This prevented more than one student from attempting to start the course at the same time.
The gates for controlling the flow of students initially had many problems. The first version of Rafting Adventures had invisible gates which did not work well with students. The students complained from not being able to move forward on the course because they did not know where the gates were. Because students were surrounded by invisible walls, they would attempt to move the raft off the course and sometimes they would succeed. Students would stand up and get off their raft which causes their raft to disappear after a short period of time. Initially when students do go off course or stand up, the entire game would need to be reset because it means the gate behind that student would never be unlocked and no one could move forward anymore. The problem was solved in two ways. Gates were given a texture in order to make students more aware that they could not move forward so they would not go off course. A reset button was customized to be able to reset any particular checkpoint or animation on the course. These changes to Rafting Adventures made the game easier to use in the classroom.

*Mystery School*

The Mystery School game was designed to teach students about differences between observations and inferences. In Mystery School, students explore a school building in order to solve the mystery of a missing class pet. Each room in the school has a pet associated with it and students must use the clues gathered in each room to find out which pet is not missing from the school. The educational content is taught by having students label clues as either an observation or inference as seen in Figure 12. After labeling all of the clues, students are then rewarded with the ability to drive different
vehicles based on how many clues they labeled correctly. Mystery School was the last
game developed by the author from the games discussed in this thesis.

Figure 12. Labeling of Clues as Observation or Inference in Mystery School Screenshot
(Captured by Author in Second Life)

The game is started by attaching the HUD, which is obtained in front of the school building. Like the other games, users must first type their name and take the pre-
test. Then users are instructed to enter the school to start playing the game. Upon entering
each room of the school, the HUD will automatically display the list of clues for that room. Each room has three clues which must be labeled as either an observation or inference. While labeling the clues, the user must take note of the pet that the clues describe. They will then mark this pet off on the pet list and continue on to the next room.
Each of the eight rooms in the game has a pet associated with it. To increase the replay value of the game, nine pets exist and each room can be associated with one of two pets. This allows any of the nine pets to randomly be used by the HUD as the missing pet. Another feature the Mystery School HUD provides is a map for navigating the rooms in the building. As seen in Figure 13, the map displays the rooms that students have not completed labeling clues for.

*Figure 13. Mystery School Map on HUD Screenshot (Captured by Author in Second Life)*

Once all the clues have been labeled as an observation or inference, the user must visit the garage area outside to have their answers checked and to receive their reward. Upon entering the garage, users first take the post-test before viewing the results from the
game. Students will then receive a high score in the game based on how fast they complete the game and how many clues were labeled correctly. Four different vehicles are available as rewards at the end of the game depending on how many clues were labeled correctly. A minimum of 15 of the 24 questions must be correct for the minimum reward to be obtained. Students have the option of returning to the school in order to correct their answers to receive a better reward. The vehicle rewards include the ability to receive a go-kart, army jeep, four-wheeler, or hovercraft. When correcting their answers, students are able to use the map in order to view the rooms that an incorrect answer occurred within as seen in the Figure 14.

*Figure 14. Incorrect Answers Labeled on Mystery School Map Screenshot (Captured by Author in Second Life)*
Weather Challenge was developed by STEAM member Tessa Cooper for teaching cloud types and weather patterns (Cooper, Liu, Franklin, & Chelberg, 2009). This module covers indicators 5, 6, and 7 in Earth Systems for 7th grade students (Ohio Department of Education, 2002). The object of the game is to collect rain drops hiding in five different cloud types which include cumulus, stratus, cirrus, nimbostratus, and cumulonimbus. To collect the raindrops, avatars explore the clouds using a flying cloud that allows them to navigate through the air as seen in Figure 15.

The clouds are separated in the air by type and each cloud contains a rain drop that randomly moves around the cloud. When a rain drop is found, the user must click on it or run into it with their avatar. After the raindrop is clicked, it will move to a new location which causes users to compete in order to obtain the raindrop.
Figure 15. Weather Challenge Game by Tessa Cooper Screenshot (Captured by Author in Second Life)

When a user clicks a raindrop, the HUD will prompt the user with a series of questions that must be answered successfully in order to complete the cloud and obtain the raindrop (see Figure 16). Users are first asked what type of cloud the rain drop was found in. After identifying the cloud type, they are presented with a scenario that requires the user to identify the weather conditions that causes weather such as snow, rain, thunderstorms, etc. to occur. After collecting all of the raindrops, users will receive a score which is derived from their ability to answer the questions correctly and to finish the game quickly.
Learning Game Deployment

Second Life games were used in three of the seven schools involved with the STEAM project. The game deployment details in this section outline the experiences drawn from research conducted at School A, where most of the results were obtained from.

The system requirements of Second Life did impose a problem for middle schools working with the STEAM project. Even though the system requirements are modest for a 3-D based game, every school in the STEAM project that used Second Life did require hardware upgrades. In School A, the system requirements were almost met but the graphics card and memory fell short. The machines used an integrated graphics controller.
with the Intel 865G chipset but the memory was only 256 mb. Initial tests with this configuration proved that this hardware was not adequate enough to run Second Life. However when 512 mb of RAM was added, Second Life performed well using the Intel 865G chipset.

When Second Life was used in the classroom at School A with each student (20 or more students) running a client, the bandwidth problems were evident with textures downloading slowly and lag when navigating characters. These problems were resolved by allowing the students to work in pairs. When the number of Second Life clients running stayed under twenty, the clients would typically run smoothly without lag.

Using Second Life in a classroom with middle school students can initially be a challenging task. After a few sessions, students will become more accustomed to Second Life and the process of using Second Life becomes as simple as using Flash-based games. Games become more rewarding when students are more accustomed to Second Life because students are no longer focusing on learning how to play Second Life and instead focus on the content within the game (Bilyeu et al., 2008).

The first couple of sessions in the classroom are used as introductory sessions to help students become accustomed to Second Life. During the first session, students learn about the process of signing into Second Life and the controls. Usually during these introductory sessions, students are instructed to visit the Interactive Science Lab and perform either the Sugar and Water Solubility Experiment or the Redi Experiment.

At the beginning of each session, a brief overview of the game to be played and all important instructions are given. Depending on the length of the game, instructions are
intentionally kept short so students will have more time for playing the game. Appendix B contains the instruction sheet students received that outlines the controls that students would need for using Second Life. All instructions related to the particular game students play are outlined in the HUD.

Within the classroom, the most difficult part of using any video game is getting the students started playing the game. This process is more difficult in Second Life due to the fact that students require a username and password to login to the game. The grant received a list of logins to use for Second Life that was divided up among the schools participating in the grant. Each school would share the logins among all the students. The first method that was used for distributing username and passwords at School A was to distribute the login information for each student on a slither of paper that students would return at the end of class. Not all students returned the login information and some students used that information to log in during their other classes. The next method used for distributing the login information involved using entire sheets of paper with all of the logins numbered. Approximately eight login sheets were shared among all students and each student was assigned a number to use for their login. After students were logged into Second Life, the login sheets were collected. This method proved to be easier to manage the login information so that it could be shared among each class period of students.

Once students are logged in, they have to be in the correct location of the virtual world to play the game. Directions are given to students about the location of the game at the beginning of the lab session but many of the students do not find the location when logged in. Immediately after handing out the login sheets, instructors will help the
students move their avatar to the correct location on the island and assist in attaching their HUD. Typically after the first couple sessions, students will become comfortable enough to find the game that is being played on their own.
CHAPTER 5: RESULTS

Pre-tests and post-tests were developed and used to measure the effectiveness of the games for teaching the science standards. The pre-test and post-test questions were developed by both the graduate student and partner teacher who created each game. They were reviewed by fellow STEAM project members. All pre-tests and post-tests used in obtaining the results are in Appendix C. Two different research methods were used in conducting pre-tests and post-tests during the two years of research.

Research Methods

The first method used during the first year of research consisted of a pre-test before playing the game and a post-test after playing the game. During the first year of research, the main goal was to find out if Second Life could be used in the classroom. The deployment techniques were still being refined at the time and not as much emphasis was placed on evaluation of the game. All results obtained through method 1 were collected electronically through the HUD’s question interface. Due to the fact that these tests occurred through the use of the in-game HUD, students were working in pairs while taking the tests unless they played the game on their own. For method 1 the pre-tests and post-tests consisted of various amounts of multiple-choice questions. No questions were repeated from pre-test to post-test.

The second method was a more refined and controlled procedure implemented during the second year of research. This method involved two rounds of playing the game with the students grouped into two randomly selected groups. Each test in method 2 had nine multiple-choice questions with one short answer question. These questions were
randomly selected from a pool of questions that were developed for each game. No questions were repeated from pre-test to post-test. The first round of testing was done before the science content is taught in the classroom. Before playing the game one of the groups took the post-test to be a control for comparing their scores to the post-test scores from after playing the game. The other group in the first round took the pre-test before the game and the post-test at the end of the game. The second round of testing is conducted after the science content is taught in the classroom. During this round of testing, both groups took the pre-test before playing the game and then the post-test afterwards. Results in this method were obtained from each student through the use of Scantron forms.

Pre-test and Post-test Results

Results obtained through both pre-test and post-test methods were tested for normalcy using a Q-Q Plot and then analyzed using T-Tests to find the significance of the results. A Q-Q Plot is used to graph paired values to test for normalcy by affirming that the plots follow a straight line without anomalies (Wilk & Gnanadesikan, 1968). The pre-test and post-test pairs were plotted to make sure the results were normally distributed before analyzing the results. T-Tests are used to compare the means of two set of data to see if they are statistically different (Fisher, 1970). The value of t from T-Tests is used to determine of the validity of the null hypothesis (Fisher, 1970). The null hypothesis in this research states that the educational games in Second Life will provide a positive increase in student’s scores from pre-test to post-test. Results with paired data from pre-test to post-test were analyzed using dependent T-Tests. When comparing the two groups using
the T-Tests, the results will be considered statistically significant with 95% confidence if the p value (Sig. 2-tailed) is less than .05 and therefore the null hypothesis can be accepted and the results can be analyzed further (Fisher, 1970). The results that have been analyzed only include results where each individual student completed all tests required for each method. All pre-test and post-test results that do not appear in this chapter and all one sample T-Tests for each test are located in Appendix D (contains method 1 results) and Appendix E (contains method 2 results).

For each set of data the following values were calculated: mean, standard deviation, standard error, lower and upper bounds for the interval of the mean, the T-statistic, degrees of freedom, and the significance. The mean value will show the difference of the means between the pre-test and post-test. Since we are taking the pre-test score and subtracting the post-test in the analysis, a negative mean value will indicate a positive increase in scores from pre-test to post-test. The lower the value is for the standard deviation shows that the increase in students scores from pre-test to post-test were similar for each student. The standard error is correlated to the sample size where the larger the sample the less likely there is an error in our standard deviation. The upper and lower bounds indicate the range where 95% of the results will fall into. The T-statistic can be used to determine the quality of the results when compared to other T values in these results. Since we are taking differences of the pairs of pre-tests and post-test, a negative T value will correlate to an increase from pre-test to post-test. Degrees of freedom are calculated from the sample size minus one. The significance is used for determining if the results are valid when the value is less than .05.
Interactive Science Lab

For the Interactive Science Lab, results were obtained for the Sugar and Water Solubility Experiment and Fruit Fly Genetics. No results were obtained from Redi Experiment because this game was typically used to introduce students to Second Life.

Sugar and Water Solubility Experiment

The Sugar and Water Solubility Experiment was evaluated using method 1 by giving the pre-test and post-test provided in Appendix C through the HUD. The pre-test only had four questions and the post-test had seven questions. As seen in Table 3 the mean shows a significant improvement of 10 percent from pre-test to post-test. In this instance the significance is less than .05 and the null hypothesis can be accepted. Because students were evaluated using the HUD, a total of 78 results were obtained because students could quickly respond to the answers and finish both pre-test and post-test.

Table 3

Dependent T-Tests for Sugar and Water Solubility Experiment using Research Method 1 on 12/02/2006 at School A

<table>
<thead>
<tr>
<th>Pair</th>
<th>PreTest - PostTest</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-.10172</td>
<td>.25216</td>
<td>.02837</td>
<td>-.15820</td>
<td>-.04524</td>
<td>-.04524</td>
<td>-.3585</td>
<td>78</td>
<td>.001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During the testing of Fruit Fly Genetics, all results pointed toward supporting the hypothesis as shown in Table 4. The dependent T-Tests all had a significance below .05 and difference of the means all showed an increase from pre-test to post-test.

The only downside to the results was the outcome of the post-test scores by Group 2 before playing the game without instruction. This score was unusually high when comparing it to Group 1’s post-test score from after playing the game. This means that either Group 2 had better performing students or the post-test contained an easier set of questions. If the average of the scores for each group after the content was taught for Group 1 (57.10%) are compared to the average for Group 2 (64.32%), it appears that Group 2 did contain students who performed better overall. When subtracting the difference in each group’s average (7.22%) from Group 2’s post-test score before the game and without instruction (45.26% - 7.22% = 38.04%), shows a score which is lower than Group 1’s post-test score (43.94%) but does not come close to the pre-test score (24.62%). While this shows that the students in Group 2 did perform better, it did not disprove that the post-test was an easier test. More research is required to determine the quality of the post-test compared to the pre-test. The results still appeared to provide educational benefit even though they are not as clear as desired.
Table 4

Dependent T-Tests for Fruit Fly Genetics using Research Method 2 in 2007-08 School Year at School A

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Lower</td>
<td>Upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 1 BefPre – BefPost</td>
<td>-.193</td>
<td>.2208</td>
<td>-.03187</td>
<td>-.257</td>
<td>-.129</td>
<td>-6.062</td>
<td>47</td>
</tr>
<tr>
<td>Pair 1 TeacPre - TeacPost</td>
<td>-.153</td>
<td>.1941</td>
<td>.02802</td>
<td>-.209</td>
<td>-.097</td>
<td>-5.475</td>
<td>47</td>
</tr>
<tr>
<td>Pair 2 TeacPre - TeacPost</td>
<td>-.18375</td>
<td>.24014</td>
<td>.03503</td>
<td>-.254</td>
<td>-.113</td>
<td>-5.246</td>
<td>46</td>
</tr>
</tbody>
</table>

Rafting Adventures

Rafting Adventures was tested twice using research method 1 and once using research method 2. The two trials using method 1 were conducted in order to view the effectiveness of the game before the material was taught and after it was taught. Both the pre-test and the post-test had seven multiple-choice questions. While both trials showed improvement from pre-test to post-test, the significance in the second trial was above .05 therefore the results were not valid to draw a conclusion from. The drop in improvement from the first trial to the second may have resulted from students taking the same set of pre-test and post-test questions. The significant results from trial 1 can be viewed below in Table 5.
Table 5

*Dependent T-Tests for Rafting Adventures Trial 1 using Research Method 1 on 02/05/2007 at School A*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
<th>T</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreTest – PostTest</td>
<td>-0.10902</td>
<td>-0.26244</td>
<td>-0.04257</td>
<td>-0.19528</td>
<td>-0.02276</td>
</tr>
</tbody>
</table>

As seen in Table 6, using method 2 to analyze the effectiveness of Rafting Adventures did not show the desired results. Comparing the means from pre-test to post-test showed a drop in scores in every set except for Group 2’s results after instruction where their scores increased from 57.77% to 61%. Although Group 2’s scores showed an increase in this instance, the paired samples test showed these results to not be significant. Therefore, it can be concluded that none of these results showed improvement from pre-test to post-test. In further analyzing these results, a hypothesis could be formed stating that the post-test was a more difficult test than the pre-test and caused the drop in scores. This arises from the fact that the post-test scores were consistently lower than the pre-test scores. Even in the situation where Group 2 took the post-test without the game, Group 2 scored significantly lower on the post-test than Group 1’s pre-test score. In tests performed after the content was taught, the average mean for Group 1 was 58.24% and the average mean for Group 2 was 59.39%. This indicates that Group 2 did not contain poor performing students. Even though the results did not show positive improvements,
the results cannot be used to conclude that the game play was completely ineffective in providing educational benefit due to the possibility of a poorly developed pre-test and post-test.

Table 6

*Dependent T-Tests for Rafting Adventures using Research Method 2 in 2007-08*

*School Year at School A*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 BefPre – BefPost</td>
<td>15341</td>
<td>.19380</td>
<td>.03426</td>
<td>.08354</td>
<td>.22328</td>
<td>4.478</td>
<td>31</td>
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<tr>
<td>Pair 1 TeacPre – TeacPost</td>
<td>.07386</td>
<td>.16236</td>
<td>.02870</td>
<td>.01533</td>
<td>.13240</td>
<td>2.574</td>
<td>31</td>
</tr>
<tr>
<td>Pair 2 TeacPre – TeacPost</td>
<td>-.03226</td>
<td>.18858</td>
<td>.03387</td>
<td>-.10143</td>
<td>.03692</td>
<td>-.952</td>
<td>30</td>
</tr>
</tbody>
</table>

*Mystery School*

When evaluating Mystery School, the means did show a positive gain from pre-test to post-test but they did not prove to be significant results. The pre-tests and post-tests each only contained five multiple-choice questions which were not enough questions to properly evaluate the students. During these trials, not all students finished both the pre-tests and post-tests because of time restrictions. The pre-test and post-test scores both had a high average which may have resulted from the students being familiar with the content before the session. The science content in Mystery School game is listed as an indicator for both 6th and 8th grade in Ohio’s Academic Standards and the material
was covered at the beginning of the year with the scientific method content. In order to evaluate this game effectively, better pre-tests and post-tests must be developed and the game must be used before the science content is taught in 8th grade.

*Weather Challenge*

Weather Challenge was evaluated at two different schools with the majority of the results showing positive gains. As seen in Table 7, the results were significant from pre-test to post-test for both instances of Group 1 playing the game. Group 2, however, did not show significant results from pre-test to post-test with instruction. When evaluating Weather Challenge at School C, only Group 1’s results with instruction provided significant results (Table 8). Although some results did not support the null hypothesis, none of the results showed significant negative results either. These results show conclusive evidence that weather challenge does provide educational benefits.

Table 7

*Dependent T-Tests for Weather Challenge using Research Method 2 in 2008-09*

*School Year at School B*

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 BefPre - BefPost</td>
<td>-.14074</td>
<td>.21530</td>
<td>.04143</td>
<td>-.22591</td>
<td>-.05557</td>
<td>-3.397</td>
<td>26</td>
</tr>
<tr>
<td>Pair 1 TeacPre - TeacPost</td>
<td>-.09259</td>
<td>.17080</td>
<td>.03287</td>
<td>-.16016</td>
<td>-.02503</td>
<td>-2.817</td>
<td>26</td>
</tr>
<tr>
<td>Pair 2 TeacPre - TeacPost</td>
<td>-.04667</td>
<td>.16344</td>
<td>.02984</td>
<td>-.10770</td>
<td>.01436</td>
<td>-1.564</td>
<td>29</td>
</tr>
</tbody>
</table>
Table 8

*Dependent T-Tests for Weather Challenge using Research Method 2 in 2008-09*

*School Year at School C*

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Paired Differences (Mean)</th>
<th>Std. Error</th>
<th>Std. Error (Mean)</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>Df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 BefPre - BefPost</td>
<td>-.04444</td>
<td>.20900</td>
<td>.03483</td>
<td>-.11516</td>
<td>.02627</td>
<td>-1.276</td>
<td>35</td>
<td>.210</td>
</tr>
<tr>
<td>Pair 1 TeacPre - TeacPost</td>
<td>-.13056</td>
<td>.23030</td>
<td>.03838</td>
<td>-.20848</td>
<td>-.05263</td>
<td>-3.401</td>
<td>35</td>
<td>.002</td>
</tr>
<tr>
<td>Pair 2 TeacPre - TeacPost</td>
<td>0.0333</td>
<td>.25527</td>
<td>.04661</td>
<td>-.09198</td>
<td>.09865</td>
<td>.072</td>
<td>29</td>
<td>.943</td>
</tr>
</tbody>
</table>

**Classroom Observations**

The simple controls of Second Life worked well for students and they would typically learn the controls quickly. The most common problem related to controls dealt with the student’s ability to navigate their avatar to the locations of the games in the virtual world. This problem resulted from students not being familiar with the virtual world they were in. This would be a problem for any new user to a virtual world that they are not familiar with. When students would have questions about how to play a learning game, the answer would typically be displayed in the text displayed on their HUD. These questions would result from students trying to play the game while ignoring the directions in the HUD. These questions are common to any classroom environment when students do not pay attention to directions. A few occasions did result in students finding errors in the directions that required clearer instructions.
Students did not mind working in pairs and those who wanted to work alone were allowed to do so. This provided other benefits to the students such as allowing them to work together to play the game. It allowed students who are more familiar with playing 3-D computer games to navigate and allow others who may become frustrated with the controls to give directions. Students were encouraged to take turns playing the game and to replay the game switching roles.

The ratio of time effectively spent learning in Second Life to the time students spent playing around in the virtual world can be a major disadvantage. Lab sessions would typically focus on playing a single game each session because of time constraints. Students that complete the games quickly can experience a lot of downtime where they are not being productive in learning. Students are encouraged to try other games in Second Life but due to lack of instruction on how to play the other games and lack of time the students usually do not finish the other games. During downtime, students would typically end up playing with the different features of Second Life such as customizing their avatar.

While using the Interactive Science Lab in the classroom, students were observed ignoring text within the HUD. A majority of the educational content lies in the HUD for the Interactive Science Lab, which may be ignored by the students. Two different approaches were implemented in newer games after observing this behavior. New games were designed to teach the educational content using more established techniques such as integrating the content into the gameplay (Fisch, 2005) or to make it a requirement in the
game that the students have to learn the material in order to complete the game by using questions with feedback of their results (Fisch, 2005).
CHAPTER 6: CONCLUSIONS

This section summarizes the thesis and draws conclusions from the results. An analysis is provided for using the games in the classroom with respect to the design choices and observations of the students.

Findings

During this research, educational science games were designed and developed within the 3-D online virtual world of Second Life. These games were evaluated in the classroom using pre-tests and post-tests. The results of the tests were statistically analyzed to determine the effectiveness of the games.

The Second Life games created during this research showed many educational benefits such as increasing student’s motivation in the classroom, stimulating the student’s interest in science, and most importantly increasing the student’s knowledge of the science content. Using the games in the classroom caused students to show an increase in enthusiasm towards science especially when the lesson plan involved video games.

The majority of the games that were evaluated showed significant improvements from pre-test to post-test. The Sugar and Water Solubility Experiment showed significant results with a 10.17% improvement in scores from pre-test to post-test using method 1. The average increase when using method 2 to evaluate Fruit Fly Genetics showed a 17.67% gain from pre-test to post-test. In the first trial of evaluating Rafting Adventures using method 1, scores increased 10.9% from pre-test to post-test. The second trial using a different set of pre-test and post-test questions provided negative results that resulted in
a 6.6% decrease in scores. These results were not significant in supporting the hypothesis. The drop in scores indicates that the tests were not effective in evaluating the game because playing the game should not cause a student’s score to decrease. Mystery School provided no significant results using research method 1 and only showed an increase of 3.03%. During the two trials of evaluating Weather Challenge, the average combined improvement was 7.42%. Not all results proved to be significant for all learning games which could have been because of the game itself or from pre-tests and post-tests that were ineffective in evaluating. While some of the results were not significant, the majority of the results showed positive gains to support the conclusion.

**Classroom Outcomes**

Most of the students were excited to play the educational Second Life games. Students enjoyed playing the games because they provided a different way of learning that they do not experience often in the classroom. Second Life provided an exciting environment that the teachers found appealing (Franklin et al., 2007). Students were always excited about Second Life and would constantly inquire the teacher about the next time they are going to use Second Life. Although a 3-D world such as Second Life can be distracting, once students start interacting with others in the 3-D world they feel more engaged (Jones, Morales, & Knezek, 2005). The student’s motivation to use Second Life drives them to overcome the technological learning challenges it may present to middle school students.

Typically a few students during each class would have complaints that resulted from them experiencing technical problems in Second Life. These games were being
field tested with the students and the lab sessions did not always run smoothly. Occasionally students would experience game play that would lag from the load on the network. At times, students would have to restart the entire game because of bugs in the games or the student not following instructions. Other frustrations resulted from students not wanting to play video games. While the majority of students do have fun with video games, not every student is going to thoroughly enjoy playing video games as previous research shows (Squire, 2005).

Even though Second Life was successfully used in the classroom during this research, many teachers may not feel comfortable using Second Life on their own in the classroom because of the complexity. Only when teachers are accustomed to playing Second Life on their own will they be able to use this technology in the classroom without having an expert on Second Life in the classroom. Many students would not have trouble learning how to play the games presented in this research without instruction but the majority of the students will require instructions. The teacher must put forth the effort to set up the lesson and learn how to play the games so they can help the students that struggle. In schools that are new to Second Life, it would require them to overcome obstacles such as hardware and network requirements along with setting up their own private island with the games provided through this research.

The most difficult part of deploying Second Life games in the classroom is the process of getting students started playing the game. For the games in this research, three steps needed to be completed for each student to begin: log into Second Life, navigate to the location of the game, and begin the game by attaching the HUD. Using the methods
outlined in Chapter 4: Learning Game Deployments, teachers can better manage their lab experience with Second Life. When students pair together, the teacher’s work is cut in half making the process even easier.

**Game Design Outcomes**

Limiting the distractions within Second Life helped students become more focused on the game they were playing. If students had the option to freely explore the world without a well defined objective, they would not hesitate to do so. The students were observed doing this during downtime before and after playing the learning games. A HUD provided students with easy to follow directions for completing each game. The buttons on the HUD limited the amount of objects that students were required to interact with. Adding a reward at the end of the game gave students an incentive to stay focused on the game.

Due to the fact that students would tend to ignore reading text in the HUD, the best way to teach the educational content is by either requiring them to answer questions or to teach it visually while they are playing the game. Games, such as Rafting Adventures, gave students a way to visualize scientific content. Students later referred to the animations of the agents of erosion and deposition in Rafting Adventures after they played the game during class assignments. Providing this 3-D representation of these scientific processes gave students a visual reminder.

Using the Question Sets system provided a convenient way to evaluate the effectiveness of the modules. When collecting pre and post test data through the HUD, occasionally students were caught responding to the questions without actually reading
them. To counteract this technique, a response time could be submitted with each answer when uploading the results to the Question Sets system. For accurate results in future STEAM research, this feature was added to both the Question Sets system and in the HUD of every game. All results presented in this thesis using the HUD were collected prior to implementing the response time feature.

Using a high score system, which is correlated to how well the educational content is learned, can be an effective motivational tool in educational games and provide replay value. During this research, the high score system did not appear to play as an important of a role in Second Life when compared to Flash-based games. The reasoning behind this may be that in Flash games students see the goal of the game as getting the best score whereas the 3-D based games are more of an adventure and the players have fun just by being able to play the 3-D game. In the Mystery School game, students tended to focus on the reward of being able to drive a vehicle and ignored their score they achieved in the game. In simpler games, such as the Sugar and Water Solubility Experiment, the high score system did succeed in adding some replay value to the game. The high scores did not appear to be as effective in this research as they were originally designed to be.

Future Work

More research could be conducted to determine the effectiveness of the games by reevaluating them with new pre-tests and post-tests. This would provide conclusive evidence that poorly designed pre-tests and post-tests did not influence the results. In games where there were beneficial results, the pre-tests and post-tests could be switched.
In others where the results were inconclusive, the pre-test and post-test questions would need to be analyzed for each question to determine if the questions in each test are equal in difficulty. The new evaluation could use the response time feature of the Question Sets system to retrieve more accurate results.

The most detrimental aspect of Second Life that was observed during class was the amount of downtime or off-task behavior that occurred. Typically the bulk of the downtime occurred during the beginning and end of the class period as students were logging into Second Life and finishing the game. The distractions in Second Life such as flying, chatting, and customizing clothing contributed heavily to the off-task behavior. Although the downtime did not appear to affect the positive results of this research, better results may be attainable if this problem is addressed. More research would be required for determining how much of the student’s time is used effectively for learning while playing Second Life.
REFERENCES


Worksheet that was used in conjunction with the game Fruit Fly Genetics game:

Name__________________

**Fruit Fly Genetics Worksheet**

Record the traits that were selected for your flies here:

<table>
<thead>
<tr>
<th>Dominant Traits</th>
<th>Recessive Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Color</td>
<td>Body Color</td>
</tr>
<tr>
<td>Eye Color</td>
<td>Eye Color</td>
</tr>
<tr>
<td>Wing Type</td>
<td>Wing Type</td>
</tr>
</tbody>
</table>

First Generation

Punnett Squares:

<table>
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<tr>
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<th>Eye Color</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>E  e</td>
<td>W  w</td>
</tr>
<tr>
<td>B</td>
<td>E</td>
<td>W</td>
</tr>
<tr>
<td>b</td>
<td>e</td>
<td>w</td>
</tr>
</tbody>
</table>

<table>
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<th>Eyes</th>
<th>Wings</th>
</tr>
</thead>
<tbody>
<tr>
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<td>%</td>
<td>%</td>
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<tr>
<td>Homozygous Dominant FF</td>
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<td>%</td>
<td>%</td>
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<table>
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<td></td>
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<tr>
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<tr>
<td>Homozygous Recessive ff</td>
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Second Generation
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Predicted Results:

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<td>%</td>
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Real Results:

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<tbody>
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</tr>
<tr>
<td>Homozygous Dominant FF</td>
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<td></td>
</tr>
<tr>
<td>Homozygous Recessive ff</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
APPENDIX B: SECOND LIFE CONTROLS

Handout that was given to students outlining the controls of Second Life:

Second Life Controls

Use the left button of the mouse to touch objects and the right mouse button to bring up menu for objects

To walk around: W A S D or ARROW KEYS

To Sit: Right click on chair and click sit

To attach HUD or goggles: 1. Open Inventory 2. Open Objects folder in inventory
                                  3. Find HUD Display then right click and select wear

To detach HUD or goggles: Right click on HUD and select detach

Alt or Ctrl: To control your camera
          Move the mouse to look around and you can also zoom in/out with the middle scroll button on the mouse

To change your appearance: Right click on yourself then click edit appearance

To Fly: Page Up Page Down
APPENDIX C: PRE-TEST AND POST-TEST QUESTIONS

This appendix contains questions for all pre-tests and post-tests used in this research.

There are a total of six sets of pre-tests and post-tests with each game having one set except for Rafting Adventures which has two sets because it was tested with both research methods. Correct answers are underlined for all tests.

Sugar and Water Solubility Experiment Pre-test

1. The first step of the scientific method is?
   A. State your conclusion
   B. Perform an experiment
   C. Form a hypothesis
   D. Make observations about the problem

2. An independent variable is?
   A. Something that doesn't change in the experiment
   B. Something that you change in the experiment
   C. Something that looks different to you
   D. Something that changes in the experiment without you changing it

3. Which of the following is the most correct statement?
   A. You can accept or reject a hypothesis, but never prove it to be true
   B. You can prove a hypothesis to be true
   C. You can prove a hypothesis to be false
   D. A hypothesis is always accepted and true

4. Which one of the following is true?
   A. Data and results are two names for the same thing
   B. Data are the facts you collect from your experiment, while Results are your interpretation of what the data means
   C. Data and results are collected before you experiment
Sugar and Water Solubility Experiment Post-test

1. What cup is the hot water cup according to your hypothesis (answer depends on your hypothesis)?
   A. Water Cup 1
   B. Water Cup 2
   C. Water Cup 3

2. Which of the following could be data from the experiment?
   A. Water cup 3 was the fastest to dissolve the sugar so it is hot water
   B. Water cup 1 took 21 seconds to dissolve the sugar
   C. Water cup 1 had the most sugar in it so it took the longest

3. Which of the following is used as the independent variable in this experiment?
   A. Type of sugar
   B. Amount of water in the glasses
   C. Water temperature
   D. Amount of sugar

4. If your hypothesis was proven right multiple times is there still a chance it could be wrong in a later experiment.
   A. Yes. It could be wrong.
   B. No. If the hypothesis is right more than once then it must always be true.

5. The first step of the scientific method is?
   A. Make observations about the problem
   B. Perform an experiment
   C. State your conclusion
   D. Form a hypothesis

6. If the results of your experiment turned out differently from what you expected then:
   A. Your experiment was a failure.
   B. You need to redo your experiment until you are right.
   C. You should explain and reflect on why it wasn't right in your conclusion.

7. Which of the following is the best conclusion if water cup 1 is the coldest water and water cup 3 is the hottest water?
   A. Sugar dissolves fastest in hot water
   B. Sugar dissolves fastest in room temperature water
   D. Sugar dissolves fastest in cold water
Fruit Fly Genetics Pre-test

1. Which of the following is the definition for heterozygous?
   A. An organism which possesses two different alleles for a genotype
   B. An organism which possesses all the same alleles for a genotype
   C. An organism which possesses three different alleles for a genotype
   D. An organism which doesn’t possess any genes that cause diseases

2. Which of the following is a genotype for homozygous recessive?
   A. bb
   B. Bb
   C. BB
   D. bB

3. What is the probability of two parents that are Bb and Bb to have an offspring with a homozygous recessive genotype?
   A. 0%
   B. 25%
   C. 50%
   D. 100%

4. Using the graph below, which type of gene do the majority of the offspring have?

   ![Graph showing the distribution of genotypes: BB, Bb, bb]

   A. Homozygous recessive
   B. Homozygous dominant
   C. Heterozygous
   D. They all have the same amount

5. If the parents are bb and Bb which of the following genotypes are not possible for the parent’s offspring to have?
   A. BB
   B. bb
   C. Bb
   D. They can have any of the traits

6. Which of the following combination of genotypes will produce the most offspring that have recessive traits?
   A. BB and BB
B. BB and Bb  
C. bb and Bb  
D. bb and bb  

7. Both parents are Ee and Ee with the dominant eye color being red while the recessive is white. Which of the following eye color phenotypes could their offspring have?  
   A. White and Pink  
   B. Pink and Red  
   C. Red and White  
   D. Only Pink  

8. Which of the following is the best definition for the term genotype?  
   A. The observable physical characteristics of an organism  
   B. An organism which contains two alleles of the same type for a particular trait  
   C. The combination of alleles that determines a specific characteristic or trait  
   D. An organism which contains two different alleles for a particular trait  

9. If the parent’s dominant eye color is brown and the recessive eye color is blue and they have a child with an eye genotype of Bb then what color is their child’s eyes?  
   A. Brown  
   B. Blue  
   C. Green  
   D. Dark Blue  

Short Answer  
10. Brown eyes are dominant to blue eyes in humans. Complete a Punnett square to determine the possible genotypes for the offspring of parents that are Bb and bb. Then give the possible phenotype(s) of the offspring.

<table>
<thead>
<tr>
<th></th>
<th>b</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
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<td>Bb</td>
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<tr>
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<td>bb</td>
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</tbody>
</table>

Possible phenotypes are brown and blue.
Fruit Fly Genetics Post-test

1. Which of the following is the definition for homozygous?
   A. An organism which possesses two different alleles for a genotype
   B. An organism which possesses the same alleles for a genotype
   C. An organism which possesses three different alleles for a genotype
   D. An organism which doesn’t possess any genes that causes diseases

2. Which of the following is a genotype for homozygous dominant?
   A. bb
   B. Bb
   C. BB
   D. bB

3. What is the probability of two parents that are BB and BB to have an offspring with a homozygous recessive genotype?
   A. 0%
   B. 25%
   C. 50%
   D. 100%

4. What is the probability of two parents that are bb and bb to have an offspring with a homozygous recessive genotype?
   A. 0%
   B. 25%
   C. 50%
   D. 100%

5. Using the graph below, which type of gene do the majority of the offspring have?

```
<table>
<thead>
<tr>
<th>Gene Type</th>
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<td>ee</td>
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</tr>
</tbody>
</table>
```

A. Homozygous recessive
B. Homozygous dominant
C. Heterozygous
D. They all have the same amount

6. If the parents are BB and Bb, which of the following genotypes are not possible for the parent’s offspring to have?
A. BB
B. bb
C. Bb
D. They can have any of the traits

7. Which of the following combination of genotypes will produce the most offspring that have dominant traits?
   A. BB and BB
   B. BB and Bb
   C. bb and Bb
   D. bb and bb

8. What is the missing genotype in the following punnett square?

<table>
<thead>
<tr>
<th></th>
<th>B</th>
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</thead>
<tbody>
<tr>
<td>B</td>
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<td>Bb</td>
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</tbody>
</table>

   A. BB
   B. Bb
   C. bb
   D. bB

9. What is the missing genotype in the following punnett square?

<table>
<thead>
<tr>
<th></th>
<th>b</th>
<th>b</th>
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<tbody>
<tr>
<td>B</td>
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<td></td>
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<tr>
<td>b</td>
<td>bb</td>
<td>bb</td>
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</tbody>
</table>

   A. BB
   B. Bb
   C. bb
   D. bB

Short Answer
10. Complete a Punnett Square for parents that are BB and Bb, and then write the percentages that their offspring will be BB and Bb.
BB – 50%, Bb – 50%
Rafting Adventures Method 1 Pre-test

1. Eroded materials can be transported distances and eventually settle to the ground in a process called _____.
   A. Deposition
   B. Transportation
   C. Erosion
   D. Abrasion

2. A _____ is formed by an alpine glacier that carves out the rugged features in a mountainous area.
   A. Mound
   B. V-shaped valley
   C. Stream
   D. U-shaped valley

3. The process of two different rock materials breaking apart at multiple rates is
   A. Deflation
   B. Abrasion
   C. Differential weathering
   D. Erosion

4. An example of a structure created by deposition is a _____.
   A. Cut bank
   B. Point bar
   C. Rill
   D. Channel

5. A steep, bare slope formed on the outside of a meandering stream or river is a(n)
   A. Point bar
   B. Oxbow lake
   C. Cut bank
   D. Creep

6. An area of nearly flat land bordering a stream that is naturally subject to periodic flooding is a
   A. Sea level
   B. Flood plain
   C. Ground level
   D. Flood bank

7. A crescent-shaped body of water formed from a single loop that was cut off from a meandering river is a(n)
   A. Oxbow lake
B. Channel
C. Meander pool
D. Inlet
Rafting Adventures Method 1 Post-test

1. The process of transporting material by wind, water, or ice to create landforms is
   A. Transportation
   B. Deposition
   C. Abrasion
   D. Erosion

2. The black rocks in the stream eroded slowly while the grey rocks eroded quickly. This is an example of
   A. Differential weathering
   B. Deflation
   C. Abrasion
   D. Erosion

3. A _____ was formed when the second glacier on the adventure carved out the steep hillsides of the valley.
   A. Mound
   B. V-shaped valley
   C. Stream
   D. U-shaped valley

4. The area where the flooded river spilled over the riverbanks to cause a flood was a
   A. Sea level
   B. Flood plain
   C. Ground level
   D. Flood bank

5. When the water rises and erodes the ground on the outside of a curve this creates a(n)
   A. Point bar
   B. Oxbow lake
   C. Cut bank
   D. Creep

6. On the inside of the curve in the meandering stream sediment was deposited to form a
   A. Cut bank
   B. Rill
   C. Channel
   D. Point bar

7. A(n) _____ was formed when the meandering river was traveling in two different paths until the deposits of sediment built up and cut a new body of water off from the river.
   A. Oxbow lake
   B. Channel
   C. Meander pool
   D. Inlet
Rafting Adventures Method 2 Pre-test

1. An area of nearly flat land bordering a stream which sometimes floods is a __________.
   A. sea level
   B. flood plain
   C. ground level
   D. flood bank

2. The process of transporting materials away by wind, water, or ice is ____________.
   A. transportation
   B. deposition
   C. abrasion
   D. erosion

3. A meandering river was traveling in two different paths until the deposits of sediment built up and cut a new body of water off from the river. This process creates a(n) _____________.
   A. oxbow lake
   B. channel
   C. meander pool
   D. inlet

4. Glaciers pick up glacial drift as they move down the mountain. This drift can do all of the following except _____________.
   A. break up more rock and material as it moves
   B. be deposited as the glacier melts
   C. break into smaller fragments
   D. contain nothing in the glacier but ice

5. The breakdown of rock by chemical or physical means is called _____________.
   A. constructive
   B. weathering
   C. deposition
   D. dissolving

6. Erosion happens at the fastest rate for which of the following situations?
   A. The water is moving slowly
   B. The water is carrying no sediments
   C. The water is moving faster
   D. The water is moving fast and carrying large sediments

7. A glacier is mainly composed of what?
   A. Rock
B. Dust  
C. Water  
D. Ice

8. Sediment is carried in the water in a moving stream. Sediments that are smaller and are carried in the water and do NOT drag along the bottom are called _____________.
   A. bed load  
   B. suspended load  
   C. deposits  
   D. sediments

9. V-shaped valleys are created by which agent of erosion?
   A. Glaciers  
   B. Streams and Rivers  
   C. Waves  
   D. Wind

10. Explain how streams erode and give an example of a landform created by stream erosion.

   Students must explain the process of erosion pertaining to streams by using terms such as bed load, suspended load, or water flow. An example must be provided such as cut bank, v-shaped valley, etc.
Rafting Adventures Method 2 Post-test

1. Eroded materials can be transported distances and eventually settle to the ground in a process called ________________.
   A. deposition
   B. transportation
   C. erosion
   D. abrasion

2. A ________________ is formed by an alpine glacier that carves out the rugged features in a mountainous area.
   A. mound
   B. v-shaped valley
   C. hill
   D. u-shaped valley

3. The process of two different rock materials breaking apart at multiple rates is ________________.
   A. deflation
   B. deposition
   C. differential weathering
   D. erosion

4. An example of a structure created by stream deposition is a ________________.
   A. cut bank
   B. point bar
   C. v-shaped valley
   D. channel

5. If hard rocks in the stream eroded slowly while the softer rocks eroded quickly, this is an example of ________________.
   A. differential weathering
   B. deflation
   C. abrasion
   D. erosion

6. On the inside of the curve in the meandering stream sediment was deposited to form a ________________.
   A. cut bank
   B. rill
   C. channel
   D. point bar

7. Sea caves are mainly made by what action?
A. Slow moving water  
B. Wind blowing against the rock  
C. Hard rocks being created  
D. Waves breaking apart rock

8. Glaciers that are located on the tops of mountains that carve out features are called___________.  
   A. alpine glaciers  
   B. u-shaped valleys  
   C. continental glaciers  
   D. ice

9. Meandering streams are streams that___________________.  
   A. curve back and forth  
   B. run straight  
   C. flow slowly  
   D. are flat

10. Explain how waves erode and give a landform created by wave erosion.

    Students must explain the process of erosion pertaining to waves by using terms such as mechanical weathering, chemical weathering, or pounding of waves. An example must be provided such as sea cave, sea arch, etc.
Mystery School Pre-test

1. Which of the following is the definition of observation?
   A. A hypothesis that has not been tested
   B. To take note of something from using your senses
   C. To make a conclusion in an experiment
   D. A guess of what you saw happen

2. Inferences are based on _____________.
   A. Thoughts
   B. Ideas
   C. Results
   D. Observations

3. Which of the following is an observation?
   A. It is going to rain because it is cloudy outside
   B. It is raining
   C. Since the sun is not shining it will rain
   D. When the wind is blowing it is raining

4. In an experiment if someone notices that ice melts faster in hot tea rather than cold water. This is an example of what?
   A. An observation
   B. A conclusion
   C. A generalization
   D. An assumption of the investigation

5. An inference is a(n) ________________ based on ones observations.
   A. Educated guess
   B. Data table
   C. Fact
   D. Thought
Mystery School Post-test

1. Which of the following is the definition of an inference?
   A. To conclude something because of what you already know
   B. To see something happen and make a conclusion
   C. To infer from using your senses
   D. To find a conclusion in an experiment

2. Which of the following is a prediction rather than an observation?
   A. The mass of the sugar measures 30g
   B. Warm water will dissolve sugar faster
   C. It is sunny outside
   D. The beaker holds 50 mL of liquid

3. Which of the following is an inference?
   A. It is going to rain because it is cloudy outside
   B. The grass is wet
   C. The skies are cloudy
   D. This beaker can hold 50 mL

4. Observations are usually made by producing descriptions based on observations made with the/a ___________.
   A. Calculator
   B. Microscope
   C. Senses
   D. Meter stick

5. An observation is usually a(n) ____________ of an event.
   A. Story
   B. Experiment
   C. Data collection
   D. Description
Weather Challenge Pre-test

1. What type of cloud is shown in the sketch?
   A. Cirrus
   B. Cumulus
   C. Stratus
   D. Cumulonimbus

2. What type of cloud is shown in the sketch?
   A. Cirrus
   B. Cumulus
   C. Stratus
   D. Cumulonimbus

3. The air temperature is 32°C, and precipitation begins to fall. What is the most likely form of precipitation at this temperature?
   A. Sleet
   B. Snow
   C. Freezing rain
   D. Rain

4. What type of weather conditions would you expect if cumulonimbus clouds are present?
   A. Lightning and strong winds are very possible.
   B. Light precipitation is likely.
   C. Precipitation will continue for 8 or more hours.
   D. Precipitation is very unlikely.

5. A warm front is approaching. What is the most likely weather forecast?
   A. The front will not move, so the weather conditions will remain constant for at least the next day.
   B. There will be quick cloud formation with brief, heavy storms.
   C. Stratus clouds will form, bringing many hours of steady precipitation.
   D. Very hot and humid conditions can be expected.

6. What types of weather conditions are associated with high-pressure systems?
   A. Air rises and clouds form quickly, leading to possible storms.
   B. Air sinks, and clouds form quickly.
   C. Clear skies and gentle breezes are present.
   D. Temperatures rise, and there will be cloudy skies.

7. What type of front usually brings stormy weather?
   A. Warm Front
   B. Cold Front
   C. No Front
   D. Mixed Front
8. What type of front forms when a mass of warm air slowly moves up and over a mass of cold, dense air?
   A. Warm Front
   B. Cold Front
   C. Stationary Front
   D. Thunderstorm

9. What does the following diagram show:

   ![Diagram of the United States with a line of thunderstorms]

   A. A warm front moving south
   B. A warm front moving north
   C. A cold front moving south
   D. A cold front moving north

10. These types of clouds indicate fair weather and are puffy and white. What type of cloud is this?
    A. Cumulonimbus clouds
    B. Cirrus clouds
    C. Cumulus clouds
    D. Stratus clouds
Weather Challenge Post-test

1. What type of cloud is shown in the sketch?
   A. Cirrus
   B. Cumulus
   C. Stratus
   D. Cumulonimbus

2. What type of cloud is shown in the sketch?
   A. Cirrus
   B. Cumulus
   C. Stratus
   D. Cumulonimbus

3. The air temperature is –5°C, and precipitation begins to fall. What is the most likely form of precipitation at this temperature?
   A. Hail
   B. Freezing rain
   C. Sleet
   D. Snow

4. It is spring, and a cold front is moving into your area. What is the most likely weather forecast?
   A. Severe thunderstorms with hail are very possible.
   B. Light winds with light precipitation are very possible.
   C. Light steady snow will fall for at least two hours.
   D. The sky will be clear with warmer temperatures.

5. What types of weather conditions are associated with low-pressure systems?
   A. Air rises and clouds form quickly, leading to possible storms.
   B. Air sinks, and clouds form quickly.
   C. Clear skies and gentle breezes are present.
   D. Temperatures rise, and there will be sunny skies.

6. The meteorologist on TV says that a cold front is moving into your area. What could you predict about the weather?
   A. Snow is on its way.
   B. Temperatures will decrease
   C. Temperatures will increase.
   D. There is a low chance of precipitation.

7. What type of weather would most likely be associated with nimbostratus clouds?
   A. Steady rain
   B. Blizzard
   C. Sunny Weather
D. Thunderstorm

8. What does the following diagram show:

A. A warm front moving south
B. A warm front moving north
C. A cold front moving south
D. A cold front moving north

9. What type of front forms when a mass of cold air moves quickly into an area?
   A. Warm Front
   B. Cold Front
   C. Stationary Front
   D. Mixed Front

10. This type of cloud forms at very high altitudes and it has a wispy or feathery appearance. What type of cloud is this?
    A. Cumulonimbus clouds
    B. Cirrus clouds
    C. Cumulus clouds
    D. Stratus clouds
APPENDIX D: METHOD 1 RESULTS

These results were obtained using method 1 during the first year of the STEAM project. All results in this appendix are additional statistics derived from the same data presented in the results section of this thesis. This appendix contains all statistics for results for the Mystery School game which did not contain any significant results.

Table 9
One Sample T-Tests for Sugar and Water Solubility Experiment from 12/02/2006 at School A

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<th>Std. Deviation</th>
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Table 10
One Sample T-Tests for Rafting Adventures Trial 1 from 02/05/2007 at School A

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<th>Std. Error Mean</th>
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Table 11
One Sample T-Tests for Rafting Adventures Trial 2 from 02/21/2007 at School A

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<td>PostTest</td>
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<td>58</td>
<td>.22637</td>
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</tbody>
</table>
Table 12

*Dependent T-Tests for Rafting Adventures Trial 2 from 02/21/2007 at School A*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>Df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreTest - PostTest</td>
<td>-.02956</td>
<td>.24048</td>
<td>.03158</td>
<td>-.09279</td>
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<td>-.936</td>
<td></td>
<td>57</td>
<td>.353</td>
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</tr>
</tbody>
</table>

Table 13

*One Sample T-Tests for Mystery School from 12/03/2007 at School A*

<table>
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<tr>
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<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
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<td>PostTest</td>
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<td>33</td>
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<td>.03928</td>
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Table 14

*Dependent T-Tests for Mystery School from 12/03/2007 at School A*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>Df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-.03030</td>
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<td>-.740</td>
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<td>32</td>
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</tbody>
</table>
APPENDIX E: METHOD 2 RESULTS

These results were obtained using method 2 during the second and third year of the STEAM project. All results in this appendix are additional statistics derived from the same data presented in the results section of this thesis.

Table 15

One Sample T-Tests for Fruit Fly Genetics in 2007-08 School Year at School A

<table>
<thead>
<tr>
<th>Group 1 PreTest - Before Game, Before Content</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>95% Confidence Interval</th>
<th>t</th>
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<tbody>
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<th>Mean</th>
<th>Std. Deviation</th>
<th>95% Confidence Interval</th>
<th>t</th>
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<tbody>
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<td>.18962</td>
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<td>18.475</td>
</tr>
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<td>.4630 .6279</td>
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<td>15.768</td>
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</table>

Table 16

One Sample T-Tests for Rafting Adventures in 2007-08 School Year at School A

<table>
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<tr>
<th>Group 1 PreTest - Before Game, Before Content</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>95% Confidence Interval</th>
<th>T</th>
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<tbody>
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<td></td>
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Table 17

One Sample T-Tests for Weather Challenge in 2008-09 School Year at School B

<table>
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<th>N</th>
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<tbody>
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</table>

Table 18

One Sample T-Tests for Weather Challenge in 2008-09 School Year at School C

<table>
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<tr>
<th>Group 1 PreTest - Before Game, Before Content</th>
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<th>Std. Deviation</th>
<th>95% Confidence Interval</th>
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