

ABSTRACT

FOLTA, ELIZABETH EASON. Investigating the Impact on Student Learning and Outdoor Science Interest through Modular Serious Educational Games: A Design-Based Research Study. (Under the direction of Dr. Leonard A. Annetta).

In an effort to get children back outdoors and exploring the natural environment, a Modular Serious Educational Game (mSEG), Red Wolf Caper, was created as part of a design-based research study. Red Wolf Caper uses a combination of an augmented reality (AR) game and a serious educational game (SEG) to capture the students' interest in the natural world around them. The game is set around a mystery in which red wolves in eastern North Carolina are being poisoned. The students are asked to portray the role of a wildlife biologist, botanist, or entomologist, whose job it is to determine who is poisoning the red wolves. MSEG are a new form of SEG that is divided into components or modules. Each module has to be completed before the player can move on to the next module. A module can take on any format, but must encompass the storyline of the game and end in an assessment. The study focused on three research questions. How would students improve the Red Wolf Caper mSEG? Do mSEG affect students' understanding in environmental education concepts, specifically, collecting, evaluating, and developing an explanation for data they collected in the game and knowledge of environmental systems and biological and social implications for the reintroduction of a species? Which role within the mSEG do the students choose and what is their reasoning behind choosing that particular role?

The game was tested by 81 middle school students during six sessions in June 2010. The study participants played the game and participated in design sessions. In addition, they were given a 5-question pretest/ posttest, role selection survey, and Serious Educational Game Rubric (SEGR). They were asked to develop a hypothesis and provide evidence to

support their hypothesis. Finally, they were asked to write a letter to a local judge explaining the importance of the red wolf reintroduction project. Twenty-three students were selected to participate in interviews to determine how to improve the game and why they chose the role they did. The mean student score for the SEGR was 18.13 out of 28. Five categories in particular stood out as needing improvement: *rules*, *increasing complexity*, *manipulation*, *identity*, and *tutorial/ practice level*. Sixty-nine completed pretests/posttests final scores were analyzed using a paired t-test ($p = 0.000046$). The letters to the judge showed that study participants understood scientific concepts and were able to apply them to real world settings that were only portrayed briefly in the game, such as the food chain. Study participants chose to play one of three roles: a wildlife biologist ($n = 64$), an entomologist ($n = 10$), and a botanist ($n = 6$). Their reason behind choosing a role included interest in learning more about the topic or the profession, a previous positive experience in that field, thought the role sounded fun or exciting, the role was better than the alternatives, or misunderstood the role.

The experience overall was positive for the participants. They felt they learned how to identify tracks, scat, trees, and invertebrates depending on the role they played. The AR field tests were one of their favorite parts about the game. Only one student expressed that they did not like the game, while the others not only enjoyed playing the game, but felt that it was a good educational tool. This study explores only one possibility of how mSEGs can be used in education.

Investigating the Impact on Student Learning and Outdoor Science Interest through Modular
Serious Educational Games: A Design-Based Research Study

by
Elizabeth Eason Folta

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Science Education

Raleigh, North Carolina

2010

APPROVED BY:

Dr. Leonard A. Annetta
Committee Chair

Dr. Patricia E. Simmons

Dr. Sarah J. Carrier

Dr. Chris E. Moorman

DEDICATION

I want to dedicate this to my husband for his love and support through the entire process and to Lady, our Chesapeake Bay Retriever, for pulling through against all odds.

BIOGRAPHY

Elizabeth was born and raised in NC. She had an interest in science from an early age. Her sixth grade teacher was the first to recognize that interest and pushed Elizabeth even harder to excel in the field. Elizabeth had two loves in life; theatre, specifically stage management, and biology. She decided to pursue the theatre route for her undergraduate degree. By her junior year in college she realized stage management was not the career for her and started making other plans. She took a year off from her undergraduate program to study abroad in Australia where she took a mixture of theatre and science courses. She took the time to learn to scuba dive and to explore a number of locations in Australia. She had been told when she left that she would not be allowed to graduate with her class, so she had planned to transfer to another university to study biology when she got back. As it came closer to time for her to come home her advisor told her she would be allowed to graduate with her class. With only two trimesters left she finished her degree in stage management. Upon graduation Elizabeth immediately started taking science courses and worked full-time as a veterinary assistant. After a year of science classes, she participated in a couple of internships with the U.S. Fish and Wildlife Service. These internships opened the door for a career in informal science education. Elizabeth worked in informal education for over five years in a variety of settings while continuing her education in Natural Resources and Science Education.

ACKNOWLEDGMENTS

I would like to thank a number of people for their help and support during this study. Without the help and support of all these people my study would never have been completed in the timeframe in which I completed it and I would have missed out on a job opportunity at the SUNY-College of Environmental Science and Forestry.

I would like to acknowledge the following people who helped on this project. Thank you to:

- the staff at the Roy and Dorothy Park Alumni Center for allowing me to use their space to conduct the study
- the staff of Centennial Campus Center for Wildlife Education for their support and allowing me the center as an alternative location
- all the teachers, educators, and parents who recruited students for this study or helped me spread the word
- Sarah and Oliver with Virtual Heroes, Inc. for answering my endless questions about Adventure Lab and for finding the Adventure Lab files that were lost on my computer
- Eric Klopfer and Lisa Stump at MIT for telling me how to fix an issue I was having with MITAR
- Rebecca Cheng for being a friend and sounding board through this project and for her help during the data collection
- Brandy Bowling for suffering through the heat and a sprained ankle to chaperone students around Centennial Campus

- Rich Lamb who helped with the statistical part of the data analysis, and
- Shawn Holmes and Bill Deluca for evaluating Red Wolf Caper.

Thank you to my committee Sarah Carrier, Chris Moorman, and Patricia Simmons for providing me with advice and suggestions throughout the study. Thank you to my advisor and committee chair Dr. Annetta for providing me with endless amounts of advice and helping me restructure my project when it felt like it was falling a part.

Thank you to my family for their encouragement and support during this experience. Last, but definitely not least, thank you to my husband, Joe, who went the extra mile for me during this process. Now it is his turn.

TABLE OF CONTENTS

LIST OF TABLES	viii
LIST OF FIGURES	ix
CHAPTER ONE: Introduction	1
People Moving Away from the Natural World.....	1
Augmented Reality	3
Benefits of the Outdoors	5
Purpose of the Study	9
Design-Based Research	9
Research Questions.....	11
Hypotheses.....	11
Limitations of the Study.....	12
Definition of Terms.....	13
CHAPTER TWO: Literature Review	15
Overview.....	15
Environmental Education.....	15
Virtual Environments and SEG	25
Augmented Reality Games	29
Writing-to-learn	38
Activity Theory.....	40
CHAPTER THREE: Methods	45
Study Overview	45
Setting and Participants.....	45
Red Wolf Caper	52
Instrumentation	65
Interviews.....	68
Pilot Test.....	68
Protocol and Data Analysis	79
CHAPTER FOUR: Results.....	85
Overview.....	85
Question 1: Do mSEGS affect student’s understanding of environmental education concepts?	85

Question 2: Which role do the students choose and what is their reasoning behind choosing that particular role?	88
Question 3: How would students improve the Red Wolf Caper mSEG?	98
CHAPTER FIVE: Discussion.....	110
Overview.....	110
Question 1: Do mSEGs affect students’ understanding of environmental education concepts?	110
Question 2: Which role do the students choose and what is their reasoning behind choosing that particular role?.....	113
Question 3: How would students improve the Red Wolf Caper mSEG?	116
Activity Theory	126
Implications.....	127
Future Research	131
Conclusion	132
REFERENCES	134
APPENDICES	146
Appendix A.....	147
Appendix B	148
Appendix C	153
Appendix D.....	156
Appendix E	158
Appendix F.....	159
Appendix G.....	160

LIST OF TABLES

Table 3.1	Number of Participants Each Session	47
Table 3.2	Study participants' Weekly Activity Participation	50
Table 3.3	Study participants' Monthly Activity Participation	51
Table 3.4	Study participants' Video Game Type Preference.....	52
Table 3.5	Location of NPCs and Quizzes	61
Table 3.6	Pilot Test SEGR Mean and Standard Deviation	72
Table 3.7	Pilot Test Design Session Notes	73
Table 3.8	Research Design Matrix.....	79
Table 4.1	“Thorough” Category Comparison between Raters	87
Table 4.2	Examples of Student Comments for Choosing to be a Wildlife Biologist.....	90
Table 4.3	Study Participants' Experience as a Wildlife Biologist.....	93
Table 4.4	Study Participants' Expectations of the Wildlife Biologist Role.....	96
Table 4.5	Student and Expert SEGR Scores	99
Table 4.6	Kappa Scores by Category	100
Table 4.7	Student Comments Aligned to SEGR Categories.....	102
Table 4.8	Study participants' Comments on the Augmented Reality Portion of Red Wolf Caper	106
Table 4.9	Study participants' Favorite and Least Favorite Parts of Red Wolf Caper	108

LIST OF FIGURES

Figure 1.1.	Diagram a Modular Serious Educational Game with an augmented reality component.....	5
Figure 2.1.	Modes of Experiencing Nature and Modes of Learning in Maturation and Development	21
Figure 2.2.	Red Wolf Caper Activity System	43
Figure 2.3.	Red Wolf Caper Design Activity System	44
Figure 3.1.	Red Wolf Caper Map on Centennial Campus at NC State University	46
Figure 3.2.	Grade and gender distribution of the 81 participants in the study	48
Figure 3.3.	The four modules in Red Wolf Caper.....	55
Figure 3.4.	Red Wolf Caper game map.....	56
Figure 3.5.	Screenshots of each of the six areas in Adventure Lab	58
Figure 3.6.	An example of a quiz question.....	61
Figure 3.7.	An example of an NPC being triggered at the real world location.....	64
Figure 3.8.	Example of a warning box being displayed before a quiz was accessed on SurveyMonkey	76
Figure 4.1.	Pretest and Post Distributions	85

CHAPTER 1

Introduction

People Moving Away from the Natural World

One of the issues facing society is the loss of connection with nature. Richard Louv (2008), author of *Last Child in the Woods*, discussed how children today are suffering from “nature-deficit disorder,” which is a result of people avoiding or not taking part in nature. Valentine and McKendrick (1997) showed that children are playing less outdoors. Parents believed it was because of the lack of public facilities in or near their neighborhoods, but research indicated it was because of the changing nature of children’s play and parental anxieties (Valentine & McKendrick, 1997). Clements (2004) showed that children spend less time outdoors than their mothers did as children. Similarly, a 2008 corporate survey of 1000 American consumers showed that 84% of parents surveyed believed that it was important for their children to spend time outdoors, while 69% said their children spend less time outdoors than they did as children (“Corporate Survey Looks at Benefits of Outdoor Time”, 2008).

Three major concerns have been detected in research about children’s outdoor play; or lack thereof. One is the parents’ perceived lack of safety for the children. Many parents are concerned about the safety of their children playing outside alone or with other children. Parents are particularly concerned with kidnapping or other crimes (Clements, 2004; Louv, 2008; Valentine & McKendrick, 1997), or the potential for physical injuries including exposure to sources of pollution (Louv, 2008). Second, is that children today are “plugged in” and are growing up with technology that adults never had and are losing an interest in the outdoors. There seems to be a dependency on television and other digital media or *electronic*

diversions. Louv (2008) referenced one child, Paul, who said “I like to play indoors better, ‘cause that’s where all the electrical outlets are” (p. 10). A third reason for the decline is because of ecophobia, the fear of the outdoors and of ecological problems (Sobel, 1997). Sobel (1997) believes that children are disconnected from the natural world in their own neighborhood, but are connected with endangered species and ecosystems around the world through electronic media. Teaching children at an early age about environmental problems without an already established connection to nature can lead to ecophobia, whereas the natural tendency to bond with nature (i.e., ecophilia) is one way to fight ecophobia (Sobel, 1997).

Duda, Bissell, and Young (1998) stated that children exposed to natural areas are more likely to care about natural areas as adults. However, Pergams and Zaradic (2008) showed there is a decline in nature recreation including visitation to natural areas. Similarly, Pergams and Zaradic (2006) concluded the decline of national park visitation was negatively correlated with electronic entertainment (e.g., television, video games, home movies, theater attendance, and Internet use) and that children and adults were not spending time outside. It is possible that even though parents believe it is important for their children to spend time outdoors they are not spending time with their children outdoors or encouraging the children to spend time outdoors. In general, society is not only moving toward a sedentary lifestyle (Pergams & Zaradic, 2006), but also people are moving away from outdoor activities and toward videophilia (Kareiva, 2008; Pergams & Zaradic, 2006). Videophilia is “the new human tendency to focus on sedentary activities involving electronic media” (Pergams & Zaradic, 2006, p. 393). Because of this new sedentary trend, people are losing their

connection to the outdoors. Balmford, Clegg, Coulson, and Taylor (2002) conducted a survey of 109 United Kingdom primary school children ages 4 to 11 years and noticed that children 8 years and over could better identify Pokémon characters than natural organisms (e.g., plants, invertebrates, mammals, and birds). Overall, students were entering secondary school able to identify < 50% of common wildlife types (Balmford, et al., 2002), demonstrating a shift away from the natural world.

Augmented Reality

With more children spending more time indoors and away from nature, the environmental literacy level of the country may suffer. It is important to connect today's youth with the environment to improve the environmental literacy and health of the nation. Creating a connection to the environment is important because that connection can improve environmental attitudes as well as foster environmentally responsible behaviors in individuals. Attitudes and behaviors (or participation) are two of the five objectives of environmental education (UNESCO-UNEP, 1977).

One possible way to create a connection to the environment is to use familiar or novel technology. Modular Serious Educational Games (mSEG) that use Augmented Reality (AR) are one possibility (Annetta, 2010). Red Wolf Caper, an mSEG, was developed specifically for the purpose of trying to connect middle school students with the outdoors. Red Wolf Caper uses a combination of an augmented reality game and a serious educational game to capture the students' interest in the natural world around them. The game is set around a mystery in which red wolves in eastern North Carolina are being poisoned. The students are asked to portray the role of a wildlife biologist, botanist, or entomologist, whose

job it is to figure out who is poisoning the red wolves. Players interview a number of suspects and in the process are asked to help identify some local flora and fauna or provide more information about them. The identification takes place both in the virtual world and real world. At two points in the game, students are sent out with a handheld computer to identify tracks, scat, trees, or insects for characters in the game. A complete description of the game is provided in chapter 3. To better understand the components of Red Wolf Caper, augmented reality games and serious educational games are described below.

Klopfer and Squire (2008, p. 205) defined AR as “a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information.” Augmented reality games use a personal data assistant (PDA) with a global positioning satellite (GPS) system to guide the player through the game. This type of technology uses location information to determine what topic information is given to the students as they move throughout the natural environment. As the students explore the natural world, they are provided information through the PDA on what they should be finding, additional information on the topic, and directions on how they should proceed in their exploration.

Augmented reality is one possible component of Serious Educational Games (SEG), video games designed for educational purposes (Annetta, 2008c). SEG may be modular and split into components or levels. To move from one level to the next, the students go outdoors and complete an AR activity (Fig. 1). Once they have successfully completed the activity they are given a password to continue to the next level of the computer-based SEG. The use of this technology may be the key to connecting students, who enjoy using technology, with

the natural world. Connecting students with the natural world will expose them to a number of physical and educational benefits.

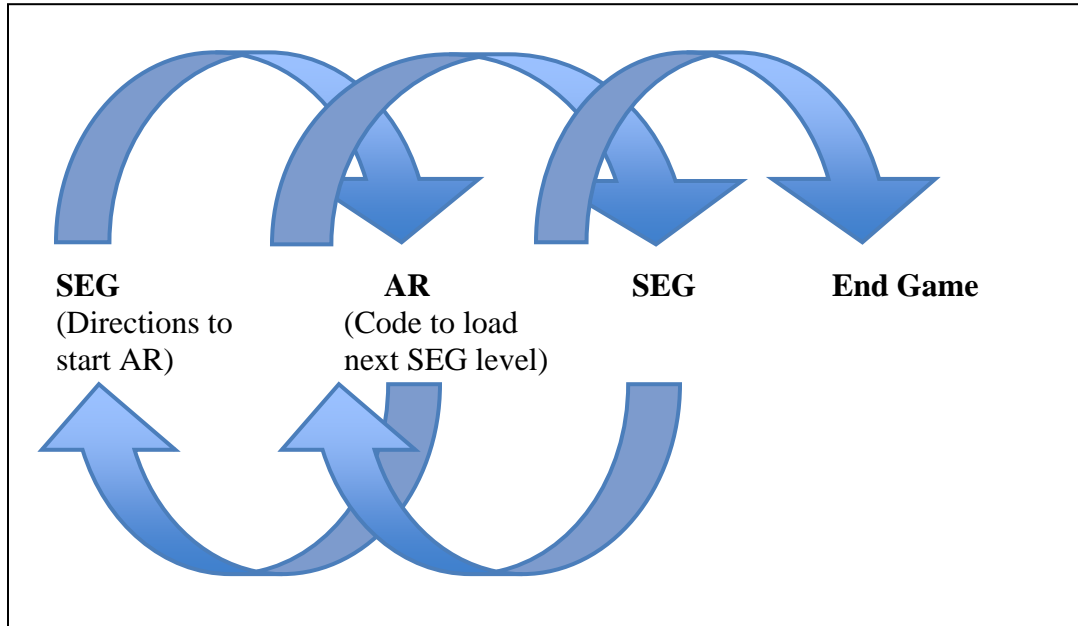


Figure 1.1. Diagram a Modular Serious Educational Game with an augmented reality component. The augmented reality component could be substituted with another activity (e.g. a computer simulation, or lab activity) (Annetta, 2010).

Benefits of the Outdoors

Physical Benefits. Spending time outdoors in natural environments (e.g., parks, schoolyards, backyards) offers both physical and education benefits to children. The physical benefits include improved vision (Rose, et al., 2008), lower stress (Wells & Evans, 2003), and the reduction of ADHD symptoms (Faber Taylor & Kuo, 2009; Kuo & Faber Taylor, 2004). One study showed that spending as little as two to three hours a day outdoors can reduce the risk of children developing near-sightedness (Rose et al., 2008). Children today are put under a lot of stress at home and school to perform. High stakes testing, high school

graduation projects, and the higher level of competition to get into colleges has recently added to that stress. In today's high-stress environments for students, outdoor time has been shown to reduce children's stress levels (Wells & Evans, 2003).

Outdoor time helps to reduce some of the symptoms of ADHD. Kuo and Faber Talyor (2004) showed that children with ADHD exhibited significantly reduced symptoms in green outdoor activities compared to activities conducted in other settings. Also, Faber Taylor and Kuo (2009) noted that ADHD children concentrated better after a walk in the park.

Although there are health benefits for children that spend time outdoors, there are health concerns when children do not spend enough time outdoors. Nature Deficit Disorder refers to children spending less time outdoors connected with the natural world (Louv, 2008). This is believed to be one of the reasons for the rise in childhood behavioral problems (Louv, 2008), depression, and obesity (Centers for Disease Control and Prevention [CDC], 2009). Vitamin D deficiency is prevalent worldwide and a lack of vitamin D in children can lead to serious illness later in life (Huh & Gordon, 2008). The absorption of ultraviolet B radiation, provided by the sun, is an important part of the body's synthesis of vitamin D.

Educational Benefits. Outdoor time has many educational benefits including improvement of the imagination, creativity, problem solving, and cooperation in children (Burdette & Whitaker, 2005). In fact, children are better able to focus on tasks after spending time outdoors and a connection to the natural worlds seems to be a key component in reducing stress and improving the attention level of children. These benefits are part of the reason for the creation of the No Child Left Inside Act.

The No Child Left Inside Act was designed to address the issue of children spending less time outdoors “by igniting students’ interest in the outdoors and spurring them to take part in outside activities. Also, learning to explore the natural world and their personal connection to it, inevitably triggers an interest in spending more time in [nature]”(National No Child Left Inside Coalition, 2010, para. 6). Recently, President Obama’s new education budget included funding for Environmental Literacy. The No Child Left Behind Act is currently being re-written into the Elementary and Secondary Education Act and the No Child Left Inside Act may become an integral component of the program. Studies such as this are needed to inform such legislation. Environmental literacy is a subset of the broader scientific literacy. Scientific literacy has been a focus of governmental legislation for years, but more recently with larger environmental concerns there has been a need to focus specifically on environmental literacy in addition to scientific literacy.

Environmental literacy is also a local focus. In North Carolina, the Office for Environmental Education has the goal of creating “Environmentally literate citizens [that] understand how natural systems and human social systems work and relate to one another, and they combine this understanding with their personal attitudes and experiences to analyze various facets of environmental issues” (North Carolina Office of Environmental Education, 2009, p. 22). Environmental Education (EE) is the most traditional approach to reconnecting children to the outdoors through fun, educational activities. These activities include playing games, doing crafts, taking a walk in the woods, or participating in pond studies. Environmental Education is designed to encourage people to spend more time outdoors, to better understand the natural environment that surrounds them, and to create a sense of

stewardship. People who spend more time outdoors may have a better understanding of the environment, which may help them make better informed decisions regarding environmental issues.

The North American Association of Environmental Education created the *Excellence in Environmental Education: Guidelines for Learning (K-12)* (Simmons, 2004) to help provide a framework for environmental education. These guidelines explain what an environmentally literate citizen should understand and be able to accomplish. This project focused on concepts in two of the four strands at the fifth through eighth grade level:

- Strand 1 – Questioning, Analysis and Interpretation Skills
 - Collecting information
 - Evaluating accuracy and reliability of information
 - Drawing conclusions and developing explanations
- Strand 2 – Knowledge of Environmental Processes and Systems
 - Organisms, populations, and communities
 - Systems and connection
 - Culture
 - Political and economic systems (Simmons, 2004)

These two strands are part of what lays the foundation for an environmentally literate individual. Strand 1 directly relates to the focus of the Red Wolf Caper, which has students collecting data and synthesizing the information to figure out who has been poisoning the red wolves. Strand 2 focuses more on the reintroduction of the red wolves both in terms of their role in the ecosystem and the cultural and social implications of reintroducing them. The

third strand focuses on understanding and addressing environmental issues and the fourth strand involves personal and civic responsibility or encouraging students to become actively involved in environmental issues both locally and globally (Simmons, 2004).

Purpose of the Study

Modular Serious Educational Games and AR are newly emerging fields with a number of possibilities for use in education. The idea of a Modular Serious Educational Game was first introduced by Annetta (2008a) . Squire and Jan (2007) examined how AR games helped with the development of argumentation skills and Klopfer and Squire (2008) discussed their seven phase developmental process for an AR game platform and then tested it with teachers and students to see how they used the platform. Also, AR games have been studied in informal education arenas such as museums (Klopfer, Perry, Squire, Jan, & Steinkuehler, 2005). In *Mystery at the Museum* (Klopfer et al., 2005) the goal was to engage visitors with the museum, the exhibits, and encourage collaboration with other visitors.

The objective of this study was to build upon their work by engaging students in informal learning environments with the natural world and improve their environmental literacy. Hence, we will develop an avenue to encourage today's technology-savvy youth to explore the natural environment using familiar and novel technologies as this project progresses through future cycles of design-based research.

Design-based research

Design-based research (DBR) methodology was used in this project because it moves educational research into the classroom and out of the laboratory, where the instructional strategies and/or tools can be tested and refined (Dede, Nelson, Ketelhut, Clarke, & Bowman,

2004; The Design-Based Research Collective, 2003). DBR occurs in cycles of design, implementation, analysis, and redesign, which is one of the five key characteristics of DBR (Barab & Squire, 2004; Dede, et al., 2004; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005). The other characteristics include developing theories, communicating implications to practitioners and educational designers, accounting for how the design functions in authentic settings, and finally relying on methods that can be documented and connected to enacting outcomes of interest (The Design-Based Research Collective, 2003).

This project was the first phase of a larger research project using AR games in environmental education. The first two iterations of the DBR cycle, the pilot test and the actual study, will lead to the next phase of the project where a more elaborate AR version of Red Wolf Caper will be created. Research question #3 (see next section) directly relates to DBR. It is common in DBR for participants to help with analyzing the design (Barab & Squire, 2004). In this case students evaluated the game then participated in a design session. The design session included ways to help improve the current game and how to move the game into more of an AR version. The plan is to create, in future iterations of the DBR cycle, a full augmented reality game that is played entirely outdoors on a smart phone or iPod® touch. The hope was by including the students in the research process they would help create a game that has more appeal to their age group and leads to a more beneficial learning experience.

Research Questions

Three research questions were investigated during this study:

1. Do mSEG affect students' understanding in environmental education concepts?
 - a. Including collecting, evaluating, and developing explanations for data they collected in the game.
 - b. Knowledge of environmental systems and biological and social implications for the reintroduction of a species.
2. Which role within the mSEG do the students choose and what is their reasoning behind choosing that particular role?
3. How would students improve the Red Wolf Caper mSEG?

Hypotheses

1. Students who participate in the modular serious educational game with an augmented reality environmental education program will show an increased understanding in collecting, evaluating, developing explanations, knowledge of environmental systems, and biological and social implications of reintroducing a species.
 - a. Null Hypothesis: Students who participate in the modular serious education game with an augmented reality environmental education program will not show improvement in collecting, evaluating, developing explanations, knowledge of environmental systems, and biological and social implications of reintroducing a species.

2. Students will choose the role that they identify with the most.
 - a. Null Hypothesis: The students will randomly choose a career path.

Limitations of the Study

Limitations of this study dealt with the AR technology and the Adventure Lab, the video game platform. The GPS unit was finicky at times depending on environmental conditions and satellite location. Some students got frustrated with having to wait for the units to collect satellites. Finally, the SEG part of the game was limited by the capabilities of Adventure Lab. The game was limited by the objects in the Adventure Lab library and the actions capable in the game. For example, instead of having a white oak (*Quercus alba*) there was only a generic red oak tree. During the Red Wolf Caper a generic tree had to be used to represent a variety of species the student would normally encounter in the natural environment during their investigations.

The weather was also a limitation of the study. On three of the four days the study was conducted, temperatures reached the upper 90s. The students spent the entire three hour session outside. The heat turned some students off to the field investigations. If the study was conducted under better conditions these students may not have had the same response.

Another limitation for this study is the ability to generalize to other types of mSEGs and video games. Modular Serious Education Games will be different depending on the components that make up the game. The results from this study could only be used to generalize to mSEGs that are comprised of SEGs and AR. Other mSEGs may include computer simulations, lab activities, or any number of different components, which are not

comparable to the mSEG used in this study. However, the information on role selection may be generalized to other SEG or AR games.

Definition of Terms

Augmented Reality (AR) – is technology that virtually overlays data and experiences onto the real world (Klopfer & Yoon, 2004). For example, a real world exploration is superimposed with virtual information supplied by a location-aware PDA.

Environmental Education (EE) – “gives people throughout the world the necessary knowledge to use nature and natural resources, to control the quality of the environment so that it is not impaired, but wisely improved - and to have the knowledge, attitudes, motivation, commitment and skills to work individually and collectively toward a solution of current problems and prevention of new ones since at present humanity has the means as well as skills to do so.” (UNESCO-UNEP, 1977, p. 40).

Formal Education – In-school learning that is normally characterized as being highly structured in a hierarchical fashion (Belle, 1982; Eshach, 2007).

Informal Education – There are multiple definitions of informal education. The broadest definition is any education that occurs outside a school setting. However, this definition is very broad so many researchers have chosen to break the learning that occurs outside of school into two categories; informal and nonformal. Informal education is the learning that occurs in everyday life and from exposure to the world around us (Belle, 1982; Eshach, 2007). Nonformal education is defined as an organized but highly adaptable educational activity that occurs outside of formal education (Belle, 1982; Eshach, 2007). Nonformal

education normally occurs in institutions or organizations (e.g., museums, after-school programs, science centers, etc.).

Green time or Outdoor time – Any time spend outside in the natural world (e.g. forest, wetlands) or semi-natural environment (e.g. schoolyards, city parks).

Serious Educational Games (SEG) – Video games designed for educational purposes (e.g., training, mission planning, etc.) compared to video games designed for purely entertainment purposes (Annetta, 2008c). Modular Serious Educational Games (mSEG) are video games made up of multiple components or modules. The modules could be in different platforms (e.g., Adventure Lab and AR) as in the case of this project or levels in the same platform. The student had to successfully complete one module in order to move to the next module in the game. To successfully complete the module, the student will have to complete an assessment. Basically, the modules can be designed in any form the designer wants as long as all the modules fit under one game umbrella so that the storyline for the game weaves through all the modules.

CHAPTER 2

Literature Review

Overview

The literature review was divided into two main areas. The first section provides background in environmental education, virtual environments and SEGs, and AR games. Each of these areas adds a component to the study. Environmental education is the foundation behind the study, whereas SEGs and AR games are the tools used. The second section provides more information on the theoretical framework – activity theory. Activity theory not only lends itself to educational gaming, but also to environmental education.

Environmental Education

Foundations of EE. Environmental education has been around for years in one form or another, but in the late 1970s it became more clearly defined by the Belgrade Charter (UNESCO-UNEP, 1975) and Tbilisi Declaration (UNESCO-UNEP, 1977). These two documents came out of international conferences held by the United Nations as part of the United Nations Environment Program (UNEP). These documents are what set the foundation for environmental education today. The Belgrade Charter stated that the generation of that time period had “witnessed unprecedented economic growth and technological progress which, while bringing benefits to many people, have also caused severe social and environmental consequences” (UNESCO-UNEP, 1975, p. 1). Even though this occurred 35 years ago many of the same things apply today. The Belgrade Charter also stated “the world’s citizens [should] insist upon measures that will support the kind of economic growth which will not have harmful repercussions on people – that will not in any way diminish their

environment and their living conditions” (UNESCO-UNEP, 1975, p. 1). They suggested environmental education is the solution to this problem. The goal of environmental education as stated by the UNEP was:

To develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations and commitment to work individually and collectively toward solutions to current problems, and the prevention on new ones (UNESCO-UNEP, 1975, p. 3).

In order to help meet this goal they listed six objectives: awareness, knowledge, attitude, skills, evaluation ability, and participation. The target audience of environmental education in the formal education sector and the non-formal education sector should be all ages of the general public (UNESCO-UNEP, 1975). Many EE programs choose to focus on children in hopes of influencing the next generation into creating a ecologically sustainable future (Duvall & Zint, 2007). Even though these programs may focus on children, some are intergenerational programs and are meant to target adults through children. Duvall and Zint (2007) reviewed seven studies on formal K-12 EE programs designed to encourage children to influence adults’ environmental behaviors, knowledge, and attitudes. The review showed that these programs only modestly influence adults. Duvall and Zint (2007) suggested that hands-on activities may potentially encourage more intergenerational communication because of the child’s excitement, but more research is needed on this topic. Red Wolf Caper was not designed for intergenerational learning, but it is possible because of the hands-on activities, some of the information was shared with adults.

Finally, the Belgrade Charter listed eight guiding principles for environmental education programs. Environmental education should:

1. ...consider the environment in its totality – natural and man made, ecological, political, economic, technological, social, legislative, cultural, and esthetic.
2. ... be a continuous life-long process, both in-school and out-of-school.
3. ... be interdisciplinary in its approach.
4. ... [emphasize] active participation in preventing and solving environmental problems.
5. ...examine major environmental issues from a world point of view, while paying due regard to regional differences.
6. ...focus on current and future environmental situations.
7. ... examine all development and growth from an environmental perspective.
8. ... promote the value and necessity of local, national and international cooperation in the solution of environmental problems (UNESCO-UNEP, 1975, p. 4).

The Tbilisi Declaration elaborated upon the goals, objectives, and principles defined in the Belgrade Charter. They reiterated that environmental education should be integrated into all levels of formal education and non-formal education. Even though the recommendation for environmental education in formal education programs of all levels was made 35 years ago, today it is still mainly a concentration of nonformal education programs in the United States. This could change if the No Child Left Inside Act is passed. In addition, they recommend that environmental education fully utilize the mass media to help create

widespread awareness and understanding (UNESCO-UNEP, 1977). Not only is it important to get traditional mass media involved, but also newer types of media (e.g., video games and social networking sites).

The Belgrade Charter (UNESCO-UNEP, 1975) and the Tbilisi Declaration (UNESCO-UNEP, 1977) laid the foundation for environmental education as it is known today. While these two documents created the goals and objectives of environmental education there have been a number of other important international legislations that has impacted environmental education. Agenda 21 (UNCED, 1992), Kyoto Protocol (UNESCO-UNEP, 1998), World Summit on Sustainable Development in Johannesburg (United Nations, 2003), and Amsterdam Conference on the Human Dimensions of Global Environmental Change (Institute for Environmental Studies, 2009) are just a few examples that have influenced environmental educators. This more recent legislation has brought forth the need for a focus on the human influences on the environment, specifically when it comes to energy sources and sustainability. The ideas presented at these meetings have expanded the emphasis of environmental education to include areas and topics related to social equity, economics, culture, and political structure (Simmons, 2004). Many of these concepts are what guided the *Excellence in Environmental Education: Guidelines for Learning (Pre K - 12)* (Simmons, 2004) which is one of the recommended frameworks for environmental education and the framework used in this study.

Environmental education should focus on problems at all levels, local to international (UNESCO-UNEP, 1977). Programs are being designed to focus on all levels, but many formal education units focus on international issues. The *Energy* unit created by Kulo et al.

(2010) is one example. Alternative energy units help address the issues mentioned in the Kyoto Protocol (UNESCO-UNEP, 1998). The Kyoto Protocol focuses on climate change and the reduction of greenhouse gas emissions. Over a five-year period participating nations are required to reduce emissions by five percent over 1990 levels. The protocol specifically calls for education at national and international levels specifically in developing nations to create public awareness. Units like *Energy* help address the concerns of the Kyoto Protocol (UNESCO-UNEP, 1998) by focusing on the world's energy resources and their impacts on the environment.

Sobel (1997, 1999) stated that teachers often focus on international issues when they should start at the local level. Sobel (1997, p. 3) said “children are becoming disconnected from their immediate environments and connected to imperiled animals and ecosystems around the world,” which leads to ecophobia. He recommended that students should not be exposed to big, complex problems (e.g., tragedies) before fourth grade (Sobel, 1999). These tragedies are beyond the conceptual and geographical scope of young students. This was one reason why *Red Wolf Caper* focused on middle school students and used an issue found in NC.

Mental Development and EE. Sobel (1997, 1999) and Kellert (2005) presented connections between a child's mental development and either environmental education or nature. Sobel (1997) described three “sensitive periods” in the lives of children for environmental education. From ages four to seven, educators should be teaching children empathy for the natural world, for ages seven to 11 the key is connecting the children with and exploring the natural world, and for ages 11 to 14 the focus should be on social actions

or specifically working on problems in their local communities (Sobel, 1997, 1999). Each of these periods is additive, so one is not left behind as the child grows older, but instead another piece is added to their education. Sobel (1999, p. 7) further stated that “seven to eleven, is the critical period for bonding with the earth.” As the child moves through each of these periods, they learn what they can do locally and globally for environmental concerns, which removes the sense of helplessness created in ecophobia. Red Wolf Caper incorporated all three of these periods: empathy, exploration, and social action into the game to make it appropriate for middle school students.

Sobel (1997) closed the paper by providing examples of how place-based education helps students connect to the environment and meet the requirements of each of the sensitive periods. Place-based education is a type of environmental education that focuses on a particular location. One simple example Sobel (1997) gave is of a goldfish pond, whereas a more elaborate example is “The Parish Maps Project.” This project focused on getting communities to make maps of their towns that showed the places that were important to them. A similar project used Geographic Information Systems (GIS) to map schoolyards and local sites including cemeteries (Kolvoord, Charles, & Purcell, 2010). Place-based education focuses on a local level, helping students to make connections to what is around them everyday. From there educators can expand to distant places, but use those connections the students already have established to help them understand, and in some cases, create a plan of action.

Whereas Sobel (1997) presented a theory on development and environmental education, Kellert’s (2005) theory is more basic. He presented a theory with the connection

between nature and mental development in children. According to Kellert (2005), children experience nature through three kinds of contact – direct, indirect, and vicarious. Direct interaction includes experiencing self-sustainable features and processes in the natural environment (e.g., plants, wildlife, and habitats). While indirect interaction deals more with experiencing nature through created or controlled environments (e.g., zoos, botanical gardens, aquariums). Vicarious interactions are nature experiences through images, representations, and other forms of expression of nature besides actual living organisms (e.g., teddy bear, stories, films, TV). Kellert (2005) then linked direct, indirect, and vicarious interactions with three forms of childhood development – cognitive, affective, and evaluative (Figure 2.1).

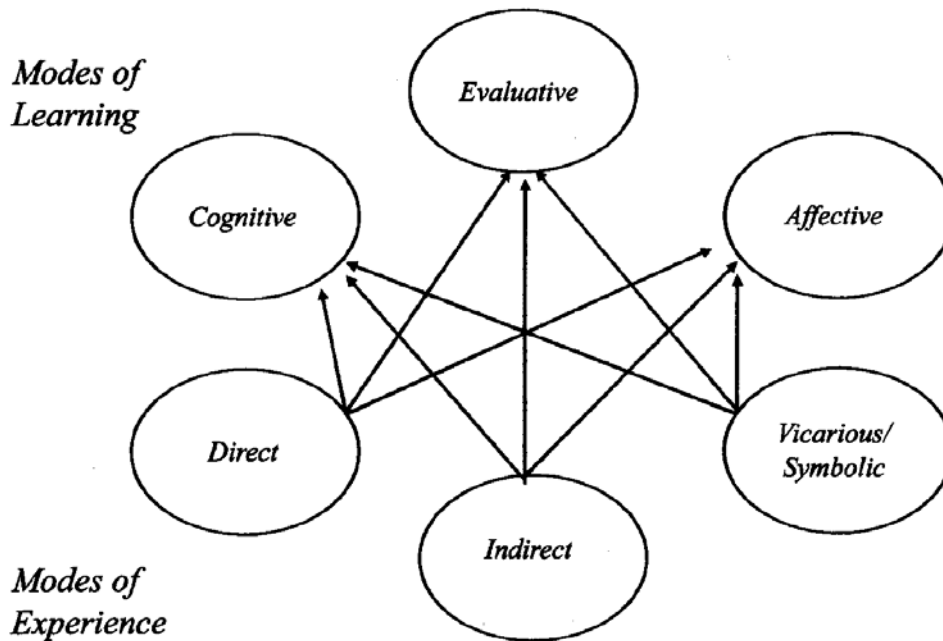


Figure 2.1. Modes of Experiencing Nature and Modes of Learning in Maturation and Development (Kellert, 2005, p. 67).

Kellert (2005) used Bloom's six stages of cognitive development: knowledge, comprehension, application, analysis, synthesis, and evaluation to demonstrate how a child's cognitive development is aided by the natural world. For example, a child's ability to classify, label, and learn about different organisms (e.g., maple tree, ants, lakes, turtles) found in nature meets the knowledge stage of development. Using a field guide or dichotomous key is an example of synthesis, where the child takes knowledge of individual parts and organizes elements into a whole.

The second type of development, affective, is represented by five stages identified by Krathwohl and his colleagues: receiving, responding, valuing, organization, characterization by a value. Kellert (2005) only considers the first two stages of this taxonomy in his theory because the last three stages are neither cognitive nor affective, but a combination of both. He describes how experiences with nature can be filled with emotions from likes and dislikes to fear and wonder.

The final area of childhood development is evaluative, which refers to a child's capacity to add a value or worth to something. Kellert (2005) explains there are nine biophilic values that form the basis of this development: aesthetic, dominionistic, humanistic, moralistic, naturalistic, negativistic, scientific, symbolic, and utilitarian. The values can be divided into three stages during a child's development (Kellert, 2005). The first stage occurs before age six and focuses on utilitarian, dominionistic, negativistic values of nature. The second stage occurs from ages six to 12 and focuses on humanistic, symbolic, and aesthetic values. The third phase occurs from ages 13 to 17 and focuses on ecological, moralistic, and naturalistic values. I assumed that ecological and scientific values were the same because

Kellert (2005) was not consistent in his use of the terminology during the course of the chapter. It is during the third phase, that according to some research, teenagers start to lose an interest in nature for more social interactions (Kellert, 2005). This is why it is important to foster a deeper connection with nature during a child's preteen and teenager years so they do not lose their interest all together. Red Wolf Caper used aesthetic, moralistic, scientific, and symbolic values to help foster this connection with nature.

In summary, direct contact with nature is important for children because it stimulates all of the child's senses and appealing to different types of development. Indirect and vicarious contact is replacing much of the direct contact that children of past generations received. They lack the same degree of challenge, adaptation, immersion, creativity, discovery, problem solving, and critical thinking that is found with direct contact to nature. Direct contact with nature, even modest and compromised settings, can strongly influence a child's development (Kellert, 2005).

Technology in Environmental Education. Many forms of technology, GIS (Kulo, et al., 2010; Tudor & Dvornich, 2001), computer simulations (Ioannidou, Paraskevopoulos, & Tzionas, 2006), Internet (Becker, Congalton, Budd, & Fried, 1998; Heimlich, 2003; Howland & Becker, 2002; Murphy & Coppola, 1997), virtual environments (Abe, et al., 2005; Ketelhut, 2007; Nelson, 2007; Okada, Tarumi, Yoshimura, Moriya, & Sakai, 2002), and AR games (Squire & Jan, 2007), have been used in environmental education, but the question related to this project was, do they engage children in the outdoors? Chavez (2009) examined four activities, two technology-dependent and two independent of technology to see which were more attractive to children. The four activities were a camera safari, nature

rubbings, geocaching, and a nature scavenger hunt. This study was conducted at a Youth Day at Griffith Park in Los Angeles. Thirty-eight participants, ages six to 17, participated in all four activities. The participants rated each activity by using green, yellow, and red cards. Green meant they liked the activity, yellow meant they were undecided, and red meant they disliked the activity.

The results were divided by activity. For the camera safari, 86% of the participants gave it a green card and 14% gave it a yellow card. It did not receive any red cards that would have indicated the participants hated it (Chavez, 2009). The observer notes also mentioned that the children were interested in the activity itself as well as the wildlife in the park. The majority of the photos taken were of vegetation and wildlife, but the participants were asked not to take pictures of other participants. The facilitators also provided positive feedback about the activity and felt the children enjoyed it.

The next activity was nature rubbings, 62% of the participants gave it a green card and 38% gave it a yellow card (Chavez, 2009). Observers noted that younger children were more interested in this activity than older ones. Some of the observers felt this activity was too easy for some of the children. The facilitators had mix feelings on the activity. Some felt the younger kids liked the activity, but the older ones did not.

Geocaching received 92% green cards and 8% yellow cards (Chavez, 2009). Observers noted that geocaching was fun for participants because of the treasure hunt, the technology, and the desire to learn more about the activity. Several kids made the comment that geocaching was the “funnest” activity of the day. They also noted that younger

participants had more difficulty with the activity than older participants. The facilitators felt the kids really enjoyed this activity.

Nature scavenger hunt received 76% green cards, 21% yellow cards, and 3% red cards (Chavez, 2009). Only one participant voted red. Observers noted a mixture of children that showed a great interest in the activity and children that did not show as much interest. The facilitators felt the children really enjoyed the activity. The overall findings showed the green card percentages were highest for the two technology dependent activities (Chavez, 2009). The observers noted that the children were interested in the activities and that they liked to be outdoors, but there was some disagreement on the age appropriateness of some of the activities. Facilitator opinions focused on the positive aspects of both the technology and non-technology activities. They felt the kids really enjoyed geocaching, camera safari, and scavenger hunt. The nature rubbing was the only activity that was questionable. The study showed that technology has a potential for getting children interested in the outdoors (Chavez, 2009).

Virtual Environments and SEG

SEGs and virtual environments are discussed together in this section because many of the games students play are in virtual environments. Both commercial games (Squire, 2005, 2006; Squire & Barab, 2004) and SEGs (Annetta, 2008b; Annetta, Minogue, Holmes, & Cheng, 2009; Dede, 2009; Ketelhut, 2007; Nelson, 2007) have been used in education, but I chose to focus only on SEGs in this literature review because of the nature of this particular study.

Benefits of Educational Gaming. “Games are no longer [just] for fun; they offer potentially powerful learning environments” (Oblinger, 2004, p. 1). The constant exposure to digital media has changed the way today’s students learn and receive information. Children are spending as much time engaged in media as they do in school (Thai, Lowenstein, Ching, & Rejeski, 2009). More specifically, students age 13-17 are spending more time with the computer and Internet than they do with television (Oblinger, 2004). Mayo (2009) stated that video games used in education could potentially equal more time on task because of the amount of time per week students normally spend on media. Also, they are adaptable to almost any subject (Annetta et al., 2009) and, in some cases, multidisciplinary in nature. Using video games in education is one method researchers are exploring to engage today’s students in learning.

Video games have been shown to offer a number of educational benefits to learning. Mayo (2009) suggested that video games could yield a 7% to 40% positive increase in learning over lectures. She suggested several benefits that games offer over traditional classroom teaching. Games can be adapted to the pace of the user unlike a lecture and it offers information in visual and auditory modes capitalizing on different learning styles (Mayo, 2009). In addition, content is reinforced through continuous and immediate feedback in a game, whereas Mayo (2009) found that, in a classroom, reinforcement was gained through 0.11 questions asked per hour. Oblinger (2004) also explained several attributes that games have that are normally associated with learning: activates prior learning, context, feedback and assessment, transfer, experiential, and social. Immediate feedback was one attribute Mayo (2009) and Oblinger (2004) listed. Games continuously offer feedback to the

players through progression through the game or advancement in level, scoring, and by ultimately winning the game. In addition, often the student can learn through failure (Squire, 2005) or trial-and-error (Oblinger, 2004). One of the most significant attributes of games is that they represent a performance-based environment, which does not allow students to take a passive role (Oblinger, 2004).

Annetta (2008b) added to the list of benefits that games offer by discussing some of the skills that players are required to use: logic, memory, problem-solving, critical thinking, visualization, and discovery. Many of these skills are the same ones required of workers in the 21st century. Video games will never replace good teaching, but they can work as a supplement to engage students in both content and give them a comfortable environment in which to learn difficult real world concepts (Annetta, 2008b).

Video games come in a variety of categories from sports games to first person shooters, but according to Amory, Naicker, Vincent, and Adams (1999), students prefer role-playing and strategy-type games. These types of games naturally lend themselves to science education. *Red Wolf Caper* takes on elements of both types of these games, but more closely resembles a role-playing game. The students took on the role of one of three characters: wildlife biologist, entomologist, or botanist. The strategy came through the manipulation of the data to determine who is poisoning the red wolves.

River City, an example of SEG. *River City* was a multi-user virtual environment funded by the National Science Foundation (Dede, 2009). The game centered on skills of hypothesis formation, experimental design, and biological and epidemiology content. Students portrayed scientists and investigated the source of the illness plaguing the town. The

results showed that the students gained in knowledge and skills of scientific learning over students involved in a equivalent experience using a board game (Dede, 2009). In addition, the students were found to be engaged in the immersive interface. Low-performing students were found to do as well as their higher-performing peers in the game (Dede, 2009).

Two other studies examined different aspects of the multi-user virtual environments (MUVE) using the game *River City*. Nelson (2007) examined the benefits of using individualized reflective guidance and Ketelhut (2007) examined student self-efficacy on scientific inquiry skills in MUVE. Comparing a group using individualized reflective guidance compared to a group that did not, Nelson (2006) found that using individualized reflective guidance in MUVE did not affect how well students did on science content tests. Many students didn't understand the individualized reflective guidance or chose to ignore it due to time constraints. Ketelhut's (2007) study on self-efficacy had more positive results. Ketelhut (2007) found that students with low self-efficacy, if given enough time (in this case three visits to *River City*) showed no difference in self-efficacy than students who originally tested high for self-efficacy. One possible reason for this was the difference between self-efficacy in using computers versus doing school work. This reinforces the idea that children are more dependent, and therefore more comfortable with technology, which explained the improvement in their self-efficacy while using computers. If this is an area of comfort for them, is it not important to encourage learning by theses means?

Virtual Environment. A virtual forest was designed for forest education by Abe et al. (2005). It used an omni-directional vision sensor to take a series of 360° photographs of a real forest. Pictures were put in a virtual environment that allowed the users to explore the

forest on established paths. The virtual forest suffered many technical problems including slow loading times as the people moved through the forest, system crashes, complicated manipulation of the pen used for drawing, and the loss of detail compared to the real forest. Even with all these problems, 88.3% of the participants said they would like to participate in a program like this again. One promising outcome of the virtual forest study for environmental education is that 90.0% of the participants said they would like to visit the real forest (Abe, et al., 2005). This is encouraging news that shows virtual worlds can be used to encourage people to visit the real thing. As technology progresses, virtual environments like this may be more beneficial to environmental education than more traditional game environments.

Augmented Reality Games

When people discuss AR games they use a variety of terms. The three main terms used are mobile gaming (Huizenga, Admiraal, Akkerman, & ten Dam, 2009; Schwabe & Göth, 2005; Spikol & Milrad, 2008), location-based games (Benford, 2005; Benford, et al., 2003; Nicklas, Pfisterer, & Mitschang, 2001; Rashid, Mullins, Coulton, & Edwards, 2006), and AR games (Dunleavy, Dede, & Mitchell, 2009; Fotouhi-Ghazvini, 2009; Johnson, 2010; Klopfer, Perry, Squire, & Jan, 2005; Klopfer, Perry, Squire, Jan, et al., 2005; Klopfer & Squire, 2008; Klopfer & Yoon, 2004; Schmalstieg & Wagner, 2007; Schrier, 2006; Squire & Jan, 2007; Squire, et al., 2007). Other terms for AR games that were not frequently used include: ubiquitous gaming (Squire & Jenkins, 2003), pervasive gaming (Klopfer & Yoon, 2004; Schmalstieg & Wagner, 2007), hybrid reality (Klopfer & Yoon, 2004), and geogame (Kiefer, Matyas, & Schlieder, 2006). Some people confuse AR with virtual reality and

geocaching, but neither of these terms accurately describes what is occurring during an augmented reality game.

Nicklas et al. (2001) divided location-based games into three categories: mobile games, location aware games, and spatially aware games. In mobile games, events only occur when two players meet. It uses proximity and local communication instead of tracking the player's location. In location-aware games, events occur when players visit certain locations, which require geographic information. Finally, spatially-aware games integrate real world surroundings into the game. In this case, game events occur in relation to the player's spatial context (e.g., entering a specific building). I will use the term "augmented reality" throughout the rest of this paper.

Augmented reality is defined as "a system of tools that allows a person to view one or more virtual 3D objects in the real-world" (Shelton, 2002, p. 1). It offers a seamless interaction between virtual and real worlds (Billinghurst, 2002). The Magicbook, an example of AR, is a normal storybook that can be read, but it also can come alive with a heads-up display. When wearing the display unit, virtual animated characters act out the story in 3D above the book (Billinghurst, 2002; Shelton, 2002). AR is being used for a variety of purposes from labeling parts of an engine (Shelton, 2002) to overlaying ultrasound images on a patient's body (Billinghurst, 2002). In education, AR could be used to model objects and allow learners to manipulate, rotate, and envision them in different environments and settings (Johnson, 2010).

Originally, a head-mounted display was used (and in some cases still is), but more applications of AR are moving toward handheld devices like PDAs and smartphones.

Handhelds have become the preferred alternative for AR for untrained users (Schmalstieg & Wagner, 2007). Mobile AR uses sensors to capture information about the user's current location and context, which allows the experience to change according to where the user is and what the user is doing (Benford, 2005). The camera and embedded screen in mobile devices provide the means for real world and virtual data to be combined (Johnson, 2010). By using GPS and image recognition AR applications can determine where the camera is pointing and overlay appropriate information at the correct locations on the screen (Johnson, 2010). There are several applications for the iPhone[®] and other smartphones that do that by relaying information on ratings, reviews, advertising, shop names, or history about the area.

An example of AR is DigitalEE, which is a proposed environment for future environmental education programs that allows users to interact and collaborate in a real forest using handheld computers, phones, digital cameras, and GPS units or through a virtual world (Okada, et al., 2002). The idea is that participants could study aspects of the forest they are in while being linked to educators and other participants around the world through a virtual environment. A GPS allows for correct placement of the area they are studying to be placed in the virtual world. Participants, who for various reasons cannot participate in the real world, can still interact in the virtual world using a computer and Internet. Okada et al. (2002) stressed the importance of the educators in this type of program and said it would not really succeed without their knowledge or expertise. Okada (2002) has planned studies to measure the effectiveness of this type of program.

Benford (2005) listed four educational uses of mobile AR: information services and guides, games, field visits, and field science. Benford describes field visits as a trip to a

historical or scientific site of interest, while field science is collecting data from a local environment. Games are probably the most compelling and commercially promising of the four options (Benford, 2005). Augmented reality games can be place-dependent or place-independent (Dunleavy, et al., 2009). Most AR games are place-dependent and designed around a specific location (e.g., *Mad City Mystery*, *Mystery at the Museum*), which may not always be the best option for education. A few games (e.g., *Alien Contact!*) have been designed so they can be superimposed onto any physical area, which allows more schools to use the game (Dunleavy, et al., 2009). Some AR games use a combination of mobile and online users, allowing them to learn together (Benford, 2005). These games can use video, text, audio, and images to go beyond just providing information to providing students with experiences (Squire, et al., 2007). AR games require a mobile device that offers either wireless networking, and/or location sensing (Benford, 2005). PDAs with external GPS units were originally used, but PDAs with internal GPS and smartphones are easier to use because everything is contained in one unit.

AR Examples. One of the games that inspired Red Wolf Caper is *Mad City Mystery*. *Mad City Mystery* is an AR game played on a handheld computer with a GPS unit (Squire & Jan, 2007). The game was designed for the participants to work together in teams of three, each of them taking on a different role. They are encouraged to explore the natural environment as they visit different locations to interview non-player characters (NPCs). NPCs are characters in the game with whom players can interact and are controlled by the computer. Each role is given different information as they interview the NPCs, which they are expected to share with their partners. They will be unable to successfully figure out the

mystery if they do not work with each other and share information. The teacher plays the role of the law enforcement officer, and when the students think they have solved the mystery, they present it to the teacher. There is no correct answer; they just have to support their hypothesis. Squire and Jan (2007) examined three case studies to see if this style of reality game could be used to engage students in scientific thinking, the impact of role playing on learning, and the role of the physical environment in shaping learning. They found “that simply participating in the game required students to weigh evidence, develop hypotheses, test them against evidence, and generate theories based on the evidence” (Squire and Jan 2007, p. 23). The roles encouraged collaboration and reading comprehension. Finally, playing in the physical environment (in this case the lake) encouraged participants to apply what they knew about local issues to the problem with which they were faced and challenged them to consider how abstract scientific concepts play out in their communities. This was also the source of the one negative comment from teachers and students. Participants felt the game was most successful when it tied to the location in a specific way (i.e., interviewing NPC fishermen on a pier), and least successful when it felt artificially layered upon the landscape (i.e., interviewing the medical doctor or family members of the victim). Other games (e.g., *Environmental Detectives*, *Mystery at the Museum*, *Alien Contact!*) take on a similar strategy of using open-ended and multiple role games (Dunleavy, et al., 2009; Klopfer, Perry, Squire, Jan, et al., 2005).

Mystery at the Museum is an example of an AR game that is played indoors. It was designed to explore parts of a museum and to encourage collaboration between visitors (Klopfer, Perry, Squire, Jan, et al., 2005). This game also is an example of how AR is being

designed for informal education. The game had specific roles, but a parent and child were teamed up in that particular role to work together.

Savannah uses a slightly different approach (Benford, 2005). The game focuses on teaching students about the ecology of the African savannah. Students work in teams, but they do not have unique rolls. Instead, they act as a member of a pride of lions. They must collaborate to scout resources and eventually decide which prey animals to attack and how many lions must attack together in order to succeed. In addition, the game allows students to return to their classroom, their “den”, between levels, and using a SMART (Self-Monitoring, Analysis, and Reporting Technology) board, replay a recording of their actions to evaluate how they performed (Benford, 2005).

AR Games and Education. Mobile technologies offers the ability to immerse learning in a natural environment (Schwabe & Göth, 2005). Augmented reality games give students experience in a variety of tasks including physical motion, problem solving, inquiry, and collaboration (Spikol & Milrad, 2008). Not only do the students participate in a variety of tasks, but also they are given the opportunity, in some of these games, to face emotionally compelling challenges, meet virtual characters, unlock new skills, and design solutions to problems (Squire, et al., 2007). Many of these games are focused around problem-based learning. In MUVES and AR games, students are given the opportunity to try different roles and learn through that identity (Squire, et al., 2007). By being focused in both the real and virtual worlds, these games can offer educators new ways to show relationships and connections to students (Johnson, 2010).

AR games can be designed to support multidisciplinary content knowledge and develop 21st century skills such as computer mediated collaboration, information sharing, managing uncertainty, and analyzing complex systems (Klopfer & Yoon, 2004). Schrier (2006) gave an example of how AR could potentially teach 21st century skills. She expanded the list of 21st century skills AR supports by including interpretation, multimodal thinking, problem solving, information management, teamwork, flexibility, civic engagement, and acceptance of multiple perspectives. Schrier (2006) further explained that AR is framed in constructivist and situated cognition pedagogy allowing learners to actively participate in their own learning. In the game, Schrier (2006) designed *Reliving the Revolution*. Participants experienced a wide range of skills including information management, media fluency, communication, critical thinking and problem solving, and collaboration. The game encouraged the students' curiosity and creativity as well as actively engaged them in the activity.

Another AR study focused on how teachers and students described the ways that AR helped or hindered teaching and learning (Dunleavy, et al., 2009). Dunleavy et al.'s (2009) research on AR games found that the use of handheld computers and GPS were highly motivating for students. Students were so engaged in the game (*Alien Contact!*) and using the units that they often ignored the physical surroundings, which could be a problem for environmental education. Students became engrossed in simple things like beaming information to one another, which led to them running out of time and not being able to collect and analyze all the data (Dunleavy, et al., 2009). Just the act of exploring the school ground was motivating for students. Applying skills related to math and science felt more

authentic in the game scenario. They noticed that students were very competitive in the game, racing to locations and talking in whispers. They also noticed that students who were normally disengaged in the classroom were engaged in the activity (Dunleavy, et al., 2009).

Many researchers agree on some of the foundations of a good AR game. Fotouhi-Ghazvini et al. (2009) said that the learning objectives must be integrated into all parts of the game (i.e., rules, story, and levels). Team members must have distinct roles (Dunleavy, et al., 2009; Fotouhi-Ghazvini, 2009; Klopfer & Squire, 2008). Even though distinct roles help to engage and get students to participate in their group, it also can be a complication. Absence of one of the roles in many cases greatly hinders the game (Dunleavy, et al., 2009). Games need to be designed so that all roles are not required to play the game. Resources should be limited (Dunleavy, et al., 2009; Fotouhi-Ghazvini, 2009; Klopfer & Squire, 2008) and appropriate challenges and feedback should be found throughout the game (Fotouhi-Ghazvini, 2009). Dunleavy et al. (2009) recommended that future AR games should offer more opportunities for deep discussion, less linear paths, and if possible, cover a large physical space.

Some educators might prefer authentic investigations, but due to time constraints, that is not always possible. Today's classroom schedules are full with the amount of material they must complete and more authentic investigations may take more time than they have to spend. Squire and Jenkins (2003) said that there is a natural overlap between hypothetical scenarios found in many of these games and real investigations. Students can participate in imaginary scenarios that take place over longer periods of time in just a few minutes or

hours. They can also master skills, test theories, and then apply them to real-world situations (Squire & Jenkins, 2003).

Besides the benefits AR offers to education there are some challenges that need to be considered. Benford (2005) listed four challenges he encountered: uncertainty of location sensing technology, uncertainty of wireless connection, interoperability of devices, networks, etc., and organizational challenges. Dunleavy et al. (2009) lumped Benford's challenges into one category (i.e., hardware and software issues) and also had two other challenges: logistical support/lesson management and student cognitive overload. They found that a minimum of two to three people were needed to manage the activity successfully (Dunleavy, et al., 2009). Students were overwhelmed and confused by some of the complex tasks and the amount of material covered during the simulation.

Weather also can be an issue. If it is too hot or too cold students engagement in the game dropped (Dunleavy, et al., 2009). Anything other than a light rain meant staying indoors.

Future. The future of AR games is moving away from handheld computers or PDAs and moving toward smartphones (Dunleavy, et al., 2009). Game developers originally treated cellular phones as another platform for a console game instead of using the mobility of the unit (Rashid, et al., 2006), but that trend is changing. There are already several AR and AR game applications for smartphones. The future may offer additional alternatives including wearable computing, smart fabrics, mobile 3D displays, and tangible embedded interfaces (Benford, 2005).

Writing-to-learn

Several studies have been done over the recent years showing the benefits of writing as a tool for science education (Hand, Hohenshell, & Prain, 2004; Hohenshell & Hand, 2006; Prain & Hand, 1996; Yore, et al., 2004). Part of what makes an environmentally or scientifically literate citizen is the ability “to communicate about inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed actions”(Yore, et al., 2004, p. 348). The written language is a key component to achieving this.

Two approaches to include writing in the science classroom include narrative (Prain & Hand, 1996; Yore, et al., 2004) and a more guided approach known as Science Writing Heuristic (Hohenshell & Hand, 2006). Prain and Hand (1996) describe narrative writing as a familiar and comfortable way for students to organize information and meaning. Examples include raps, performances, interviews, stories, and other types of writing. The major focus in evaluating narrative writing is to access the student’s understanding of concepts related to the science topic. Prain and Hand (1996) gave a model for accessing writing in science which focuses on three forms of writing: narrative, recipes/instructions, and debate/dialogue. Focusing on narrative, the model provides information on both the structural features the narrative should include (e.g., setting, plot, characters, point of view, and imaginative extension of plot) and assessment criteria listed below:

- Is time sequence appropriate?
- Do setting details indicate concept knowledge?
- Does sequence indicate understanding of casual links?

- Do characters show appropriate qualities? Are appropriate names used (standard terminology)?
- Do point of view details indicate concept knowledge?
- Are details consistent with appropriate concept knowledge?
- Is writing based on knowledge of appropriate concepts? (Prain & Hand, 1996, p. 121)

Hohenshell and Hand (2006, p. 266) described Science Writing Heuristic (SWH) as “a semi-structured experience that helps students identify patterns in their inquiry data, use their data and prior knowledge to construct and support knowledge claims, and make meaningful connections between data, claims, and evidence.” The SWH consisted of a student template designed to guide students’ thinking about science concepts and the teacher template that helps teachers create activities before, during, and after, that help enhance the understanding of those concepts. The SWH experience traditionally ends with a culminating writing task or summary report of the experience for the students. Hohenshell and Hand (2006) showed that this type of experience resulted in better student performance on conceptual questions compared to students writing a traditional laboratory report.

A combination of narrative and Science Writing Heuristic was used in this study. The students were assigned the task of writing a letter to a local judge explaining why the red wolf reintroduction project was important. A letter to a judge was used to keep in the theme of the investigation. During their investigation the students had a field observation sheet on which they could take notes. It prompted them to write a hypothesis and provide supporting evidence, which hopefully helped the students to start identifying patterns in their data that related to the overall topic of the red wolf reintroduction.

Activity Theory

Activity theory was the theoretical framework used for this study. This framework analyzes human practices on individual and social levels concurrently (Mwanza, 2001). Lim and Hang (2003, p. 51) define the Activity System basic unit “as a unit of analysis allow[ing] one to observe the actual processes by which activities shape and are shaped by their context.” In this paper, the expanded version of the mediational triangle designed by Cole and Engeström (1993) was used in all figures to represent the activity system. The activity systems are dynamic and can be influenced by sources outside of the immediate system (Lim & Hang, 2003). Moeller, Cootey, and McAllister (2007) simply defined the six fundamental elements that are carefully studied in the activity system:

- activity: outcome-oriented actions toward a predetermined goal
- object: the goal of the activity
- subjects: the actors who perform the activity
- artifacts: objects that mediate the activity
- community: contextual influences like rules, roles, and users that influence the activity
- outcome: the result of the activity (Moeller, et al., 2007, p. 136)

Isolating these elements of the activity systems into parts allows designers and teachers to better understand the complex meaning-making activities that students undertake when designing a content-based computer game (Moeller, et al., 2007), but the same could be potentially applied to students evaluating and playing a computer game. Activity theory

looks for contradictions created in the goals for the activity and the mediating artifacts of that activity (Moeller, et al., 2007).

Mwanza (2001) developed a methodology for computer system developers to direct the application of activity theory. The methodology is intended only for the capture phase of design. The capture phase is for establishing what the end-user wants from the computer system. Mwanza (2001) developed six stages for operationalizing activity theory.

1. Model the situation being examined
2. Produce an Activity System of the situation
3. Decompose the situation's Activity System
4. Generate research questions
5. Conduct a detailed investigation
6. Interpret findings (Mwanza, 2001, p. 5)

Activity theory has been used in several technology related studies (Chen, Lai, Yang, Liang, & Chan, 2008; Lim & Hang, 2003; Moeller, et al., 2007). Lim and Hang (2003) used activity theory to examine the integration of information and communication technologies into schools in Singapore. Activity theory helped them to document and describe activity systems across schools and classrooms. It also allowed the researchers to understand how larger entities (i.e., administrators and policymakers) impacted activities. Chen et al. (2008) used activity theory to investigate the effects of mobile technology on outdoor experiential learning. They used PDAs and digital cameras to support an outdoor activity on African touch-me-not (*Impatiens walleriana*). Activity theory allowed them to further understand the affordances and constraints of mobile technology in this case. By breaking down the triangle

into sub-triangles, they were able to identify the internal contradictions in rules, community, and tool components. Moeller et al. (2007) used activity theory to investigate project management and educational game design. In the case of *Aristotle's Assassins*, the execution of the game design strategy took place in the activity system. The design meetings were the activity and the object was the creation of the game. Activity theory allowed them to draw conclusions about their design process. For example, rules always affect the outcome. In this particular case, a lot of the work had to be done outside the lab due to the lab hours, which caused a feeling of isolation among team members and a sense of disconnect from the game they were creating.

Activity theory was beneficial for the Red Wolf Caper project in two ways. First, It served as a means for looking at the mSEG in its current state, similar to what Chen et al. (2008) did in their study. In this case, playing the game was the activity and the object was to synthesize the data in the game and learn basic identification skills (see Figure 2.2). The second use of activity theory came with revisions or redesigning of the game. Using a similar strategy as Moeller et al. (2007), the design sessions with the students were the activity and the object was to improve the mSEG and full AR versions of the game (see Figure 2.3).

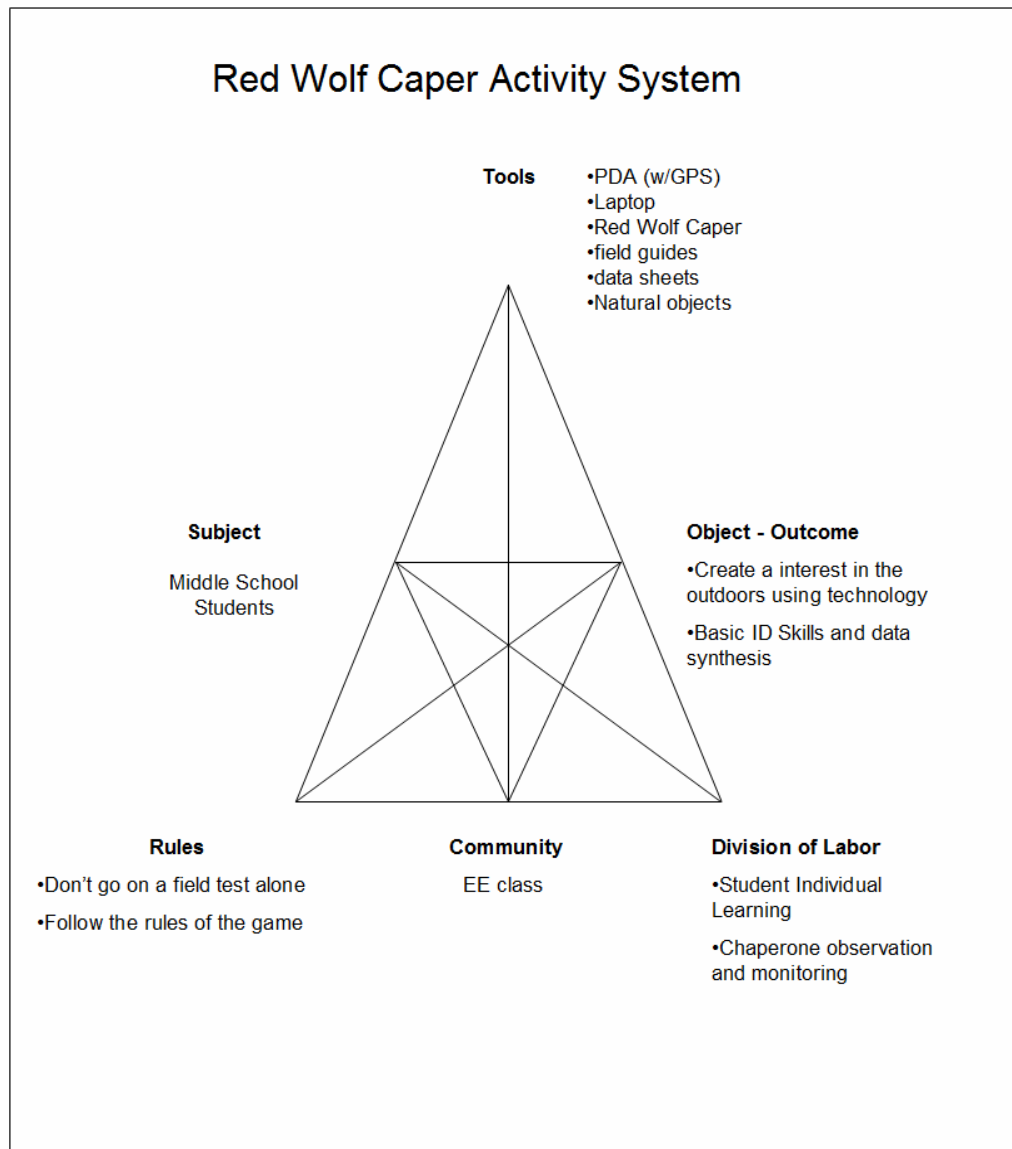


Figure 2.2. Red Wolf Caper Activity System (adapted from Cole & Engerström, 1993)

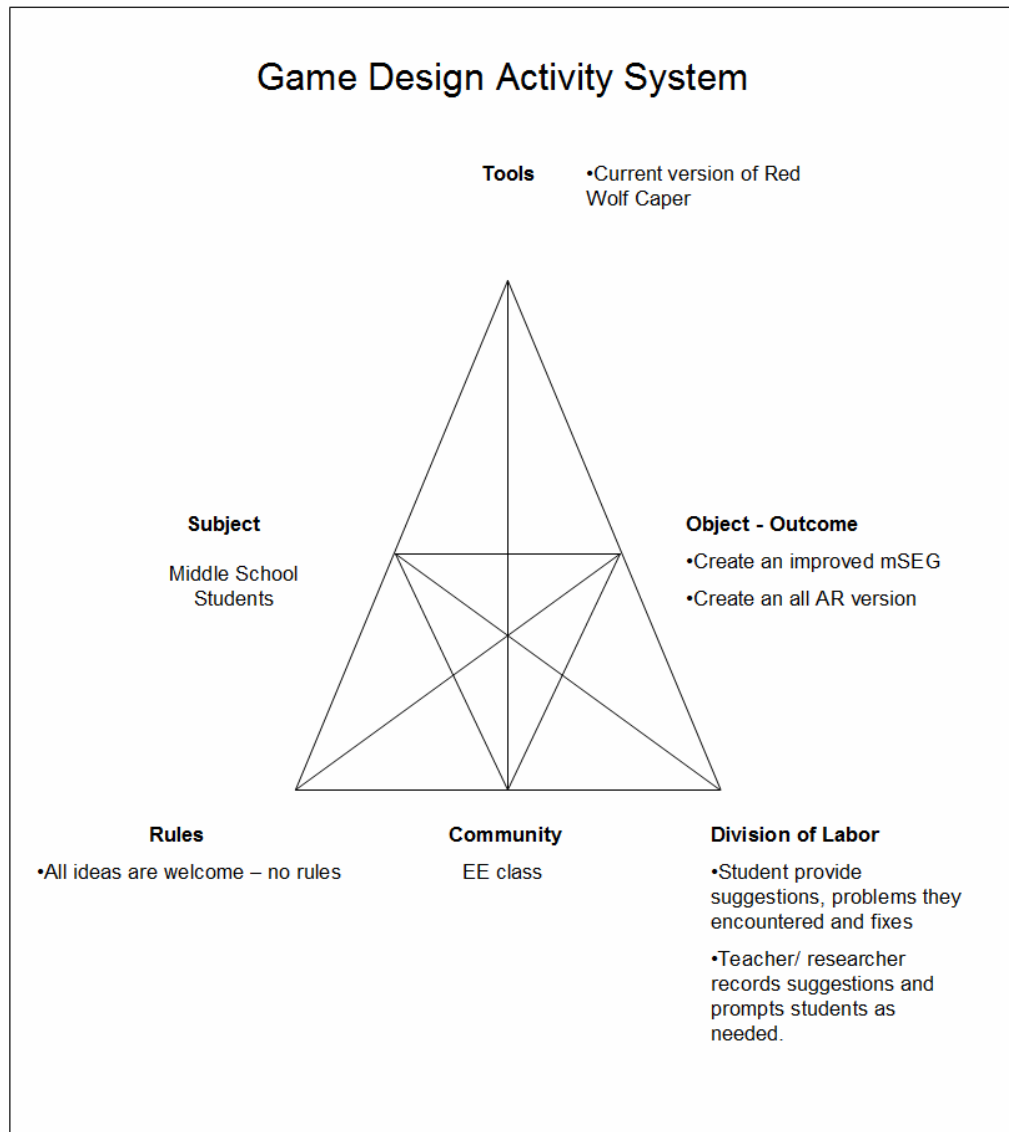


Figure 2.3. Red Wolf Caper Design Activity System (adapted from Cole & Engerström, 1993)

CHAPTER 3

Methods

Study Overview

This study was designed to test the use of mSEGs in an informal science education setting, specifically environmental education programs from the participants' viewpoint. Using a mixed methods quasi-experimental approach, three research questions were investigated: (a) Do mSEGs affect students' understanding in environmental education concepts? Specifically, do mSEGs affect students' understanding of collection, evaluation, and explanation of data as well as the knowledge of environmental systems and their biological and social implications for the reintroduction of a species? (b) Which role do the students choose and what is their reasoning behind choosing that particular role? (c) How would students improve the Red Wolf Caper mSEG? These questions led to information that will help encourage children to spend more time outdoors exploring the natural environment.

Setting and Participants

The SEG component of the game took place on the back patio outside the Dorothy and Roy Park Alumni Center, and the AR component took place on the grounds of Centennial Campus around the Park Alumni Center, Lake Raleigh, and the Lonnie Poole Golf Course (Figure 3.1). Centennial Campus is part of North Carolina State University and offers a mixture of recreational opportunities (e.g., lake open to fishing and boating, golf course, and walking trails in Quay Woods), residential housing (e.g., The Shores), and research community (e.g., government offices, private industry, and college departments).

The study participants explored Quay Woods, early successional habitat, the edge of Lake Raleigh, and a landscaped yard.

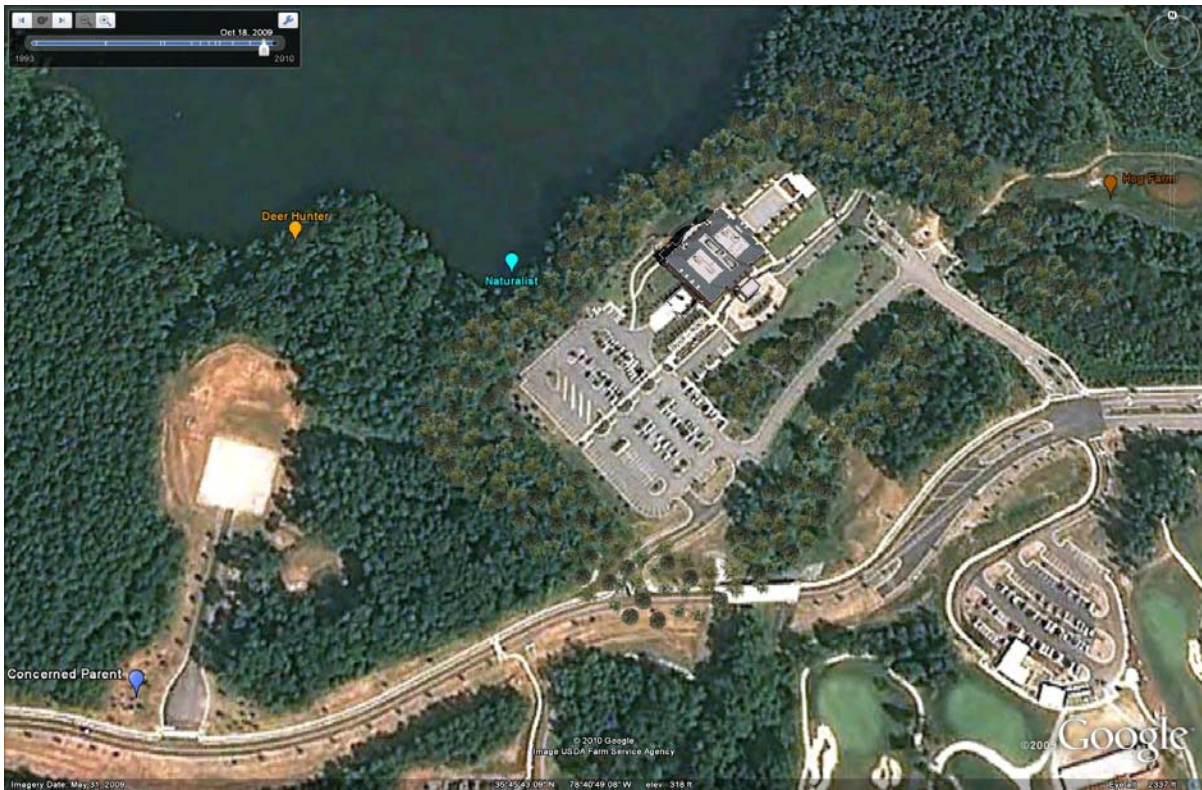


Figure 3.1. Red Wolf Caper Map on Centennial Campus at NC State University.

The study was conducted on June 21-23, 2010. Two sessions were held each day: one in the morning (i.e., 9-12 pm) and one in the afternoon (i.e., 1-4 pm). Due to the amount of equipment and number of chaperones for field tests, each session was capped at 15 students, but on one occasion we had more than 15 participants (Table 3.1). On that occasion the back-up computer and the researcher's personal computer were used. Participants included a total of 95 middle school students between the pilot study ($n = 14$) and the main study ($n = 81$). The pilot study will be discussed later in this chapter. The main study group consisted of 67

Caucasians, 6 African Americans/blacks, 7 other students representing minority groups, and one unknown. This project was conducted in June 2010 when many students were out of school for the year. For the purposes of this study, middle school students were classified as rising 6th graders through rising 9th graders (Fig. 3.2). A convenience sample of local middle schools and home school students were originally recruited by using three listservs: Middle Educators Global Activities (MEGA), NC-Environmental Education, and NC SciTeach. Chapel Hill’s Homeschool, a fourth listserv, was included after the pilot test. Students were recruited through fliers (Appendix A) distributed through these listservs, by their middle school teachers who participate in one or more of these listservs, and by word of mouth. A total of 101 students were recruited with several more on the waiting list for two of the sessions. Seven students dropped out before their session due to illness, lack of transportation, and other obligations; two students simply did not show. One unregistered student showed up the last day and was allowed to participate. Students were compensated for their participation with a \$15 iTunes® gift card. The final group included 73 public school students, 3 private school students, 3 home school students, and 2 unknowns.

Table 3.1

Number of Participants Each Session

Date	Morning Session (9-12pm)	Afternoon Session (1-4pm)
June 21	15	14
June 22	11	11
June 23	17	13

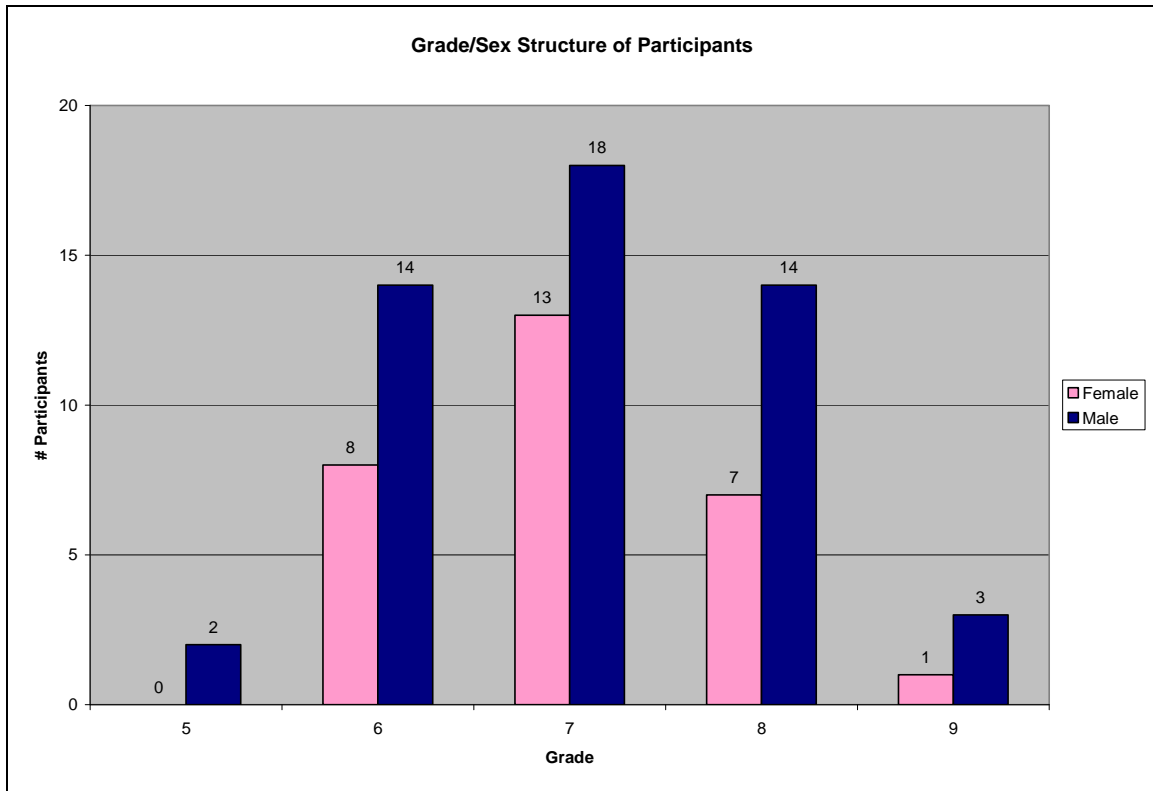


Figure 3.2. Grade and gender distribution of the 81 participants in the study. Note: One male student left his grade blank.

Study participants' Background. To better understand the out of school time activities, participants were asked to list the weekly (Table 3.2) and monthly (Table 3.3) activities in which they participated. The top three weekly activities in which study participants participated were computer, free play – outdoors, and watching TV. In addition to asking study participants if they participated in an activity, they were also asked to estimate how many hours per week they participated in that activity. Using the minimum number of hours in each range a total number of hours per week for the group was calculated. The ranges were 0-2, 2-4, 4-6, 6-8, and, <8. For 0-2, 0.5 was used for the calculation. The top three (rated in number of hours) weekly activities were organized sports, watching TV, and

free play – outdoors. In weekly activities, all 81 study participants participated in some form of outdoor activity and some form of technology activity.

The top three monthly (Table 3.3) activities in participation and number of visit per month were going to the movies, renting a movie, and visiting the mall, respectively. Visiting a park was the most common outdoor activity and ranked fourth.

Table 3.2

Study participants' Weekly Activity Participation

Weekly Activities	Do Not Participate	Number that Participate	Minimum Weekly Total Hours for the Group
Computer (surfing the Internet, social networking, etc.)	2	79	168.0
Free play – Outdoors	3	78	203.0
Watching TV	4	77	238.5
Free play – Indoors	6	75	171.0
Reading (books, comics, magazines, etc.)	7	74	198.5
Biking, rollerblading, skateboarding, scooter, go for a walk, etc.	8	73	141.0
Video and computer games (PS3, Wii, Xbox, etc)	10	71	200.0
Mobile games (Nintendo DS, PSP, iPod touch, smartphones)	20	61	97.0
Organized sports	23	58	247.0
Visual Arts (drawing, painting, sculpture, etc.)	41	40	63.0
School Clubs	54	27	49.5.0
Performing arts (dance, drama, singing)	57	24	34.5.0
Scouts (Girl or Boy Scouts)	58	23	32.0

Table 3.3

Study participants' Monthly Activity Participation

Monthly Activities	Do not participate	Number That Participate	Minimum Number of Total Visits Per Month
Go to the movies	7	74	117
Rent a movie	10	71	133
Visit the mall	16	65	98
Visit a park	26	55	95
Visit a museum	32	49	69
Camping	39	42	76
Fishing or hunting	46	35	61
Hiking	46	35	60
Boating	45	36	66
Visit an arcade	62	19	21

The final component of the background survey consisted of ascertaining the types of video games the study participants play. Not all study participants completed this section; some did not regularly play video games. Three study participants did not play video games in any form including computer, console, or mobile. Five study participants left the game section incomplete. In addition to saying what games they played, they were supposed to rank their top three. For an unknown reason, thirty of the study participants did not understand this direction and just marked their top three. The top three games study

participants ranked as their favorites were action, adventure, and racing, and the top three types of games the study participants played were racing, action, and rhythm (Table 3.4).

Table 3.4

Study participants' Video Game Type Preference

Types of games	Number of Study participants
Action - God of War, Call of Duty, etc.	52
Adventure - Lego Star Wars, Ratchet & Clank, etc.	40
Arcade - Pac Man, Space Invaders, etc.	32
Casual games - Bejeweled, solitaire, board games, etc.	32
Online Gaming - Aion, World of Warcraft, Star Wars Galaxies, etc.	36
Racing - Mario Kart, Burnout, Gran Turismo, etc.	54
Rhythm - Guitar Hero, Rock Band, Dance Dance Revolution, etc.	43
Role-Playing - Final Fantasy, Zelda, Dragon Age, etc.	27
Simulations - The Sims, Spore, etc.	24
Social applications - Mafia Wars, Farmville, etc.	19
Sports Games - Madden NFL, NBA Live, Deer Hunter, etc.	37
Strategy - Age of Empires, Civilization, etc.	26

Red Wolf Caper

Overview. Red Wolf Caper was a game designed specifically for this project. The game was modeled after other AR games (Dunleavy, Dede, & Mitchell, 2009; Klopfer, Perry, Squire, Jan, & Steinkuehler, 2005; Klopfer & Yoon, 2004; Squire & Jan, 2007). The premise of the game was that red wolves (*Canis rufus*) in North Carolina are being poisoned.

Three experts (i.e., wildlife biologist, entomologist, and botanist) have been hired to find the ingredients for the antidote and determine who is poisoning the wolves. The experts visit different locations and interview non-player characters (NPCs) to collect the evidence needed to develop a hypothesis of who is poisoning the red wolves. The study participants collected evidence to support their hypothesis.

The game was designed to take approximately two hours to complete. There was no research significance for the two hour time period. Two hours is a common time period for local environmental education center programs and school field trips. The objective of the game was to teach students how to identify red wolves, scat, tracks, plants, and invertebrates using field guides, and synthesize information they were given from multiple sources.

Modular SEG. The modules of the mSEG were developed in two different platforms: Adventure Lab and Massachusetts Institute of Technology AR (MITAR). Adventure Lab was a video game design platform created for the Games Requiring Advanced Developmental Understanding & Achievement in Technological Endeavors (GRADUATE) project and created by Virtual Heroes, Inc. (Raleigh, NC). The platform allows students and teachers to create their own video games without the need for art, animation, and other skill sets needed to create commercial video games. Instead of exploring the real world, students explored a virtual world using a virtualized setting designed to imitate Centennial Campus.

MITAR was an AR simulation engine and toolkit developed by Massachusetts Institute of Technology for the Scheller Teacher Education Program. MITAR was in its beta version 5.2 at the time of this study. This platform allows teachers to create AR simulations

for PDAs. MITAR allows the user to overlay information on a georeferenced aerial photograph. The user can upload their own aerial photograph or use the program to locate one on Google® maps. Once the location has been selected the designer can add items, non-player characters, and portals to locations on the aerial photograph. These three types of elements were triggered as the player moved to that location. In addition, images and text can be associated with the different elements that are displayed upon triggering. These locations can be turned on and off as the game progresses or through the use of numeric codes entered by the player. The AR game can be designed with multiple roles and chapters.

Red Wolf Caper was divided into four modules (Figure 3.2). Two modules were completely in Adventure Lab and the other two modules were in a combination of both MITAR and Adventure Lab. Figure 3.2 displays which platform(s) each module used. Each module ended in an assessment. The students had to complete the assessment before they could move on to the next module. In Module 1, students completed the pretest for their self-selected role. In Modules 2 and 3, students had to complete a field test, where they had to identify an object (e.g., scat, plant, or insect) and in Module 4, the students completed the posttest.

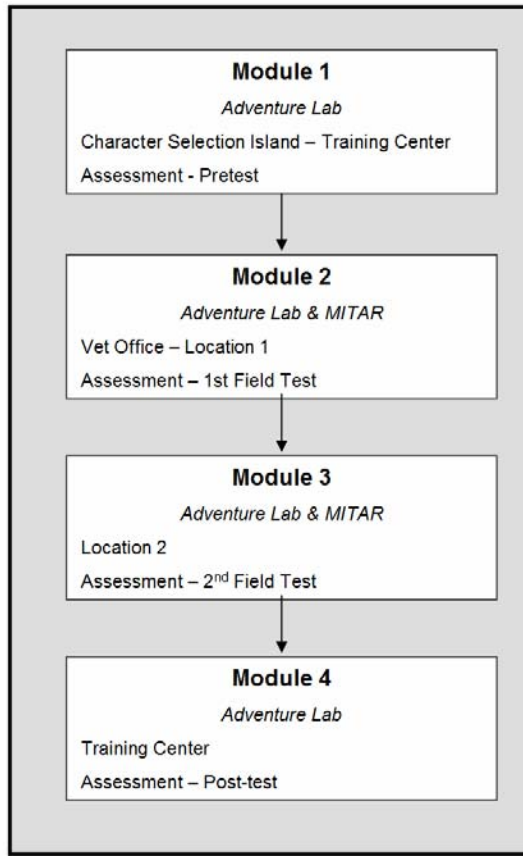


Figure 3.3. The four modules in Red Wolf Caper. Each module shows the parts of the game it covered and the assessment for that module.

Game Description. Study participants chose one of three roles (i.e., wildlife biologist, botanist, and entomologist) in which to conduct their investigation. There were different versions of the game for each role. Study participants interacted with the other two roles that they did not chose as non-player characters in the game. At the end of the two investigatory modules, modules 2 & 3, the participants received a summary of evidence the other two roles should have discovered. Students were given tasks throughout the game that related to their chosen role. For example, the wildlife biologist was asked to identify tracks and scat, whereas the botanist was asked to identify various plants. The study participants

were given field guides to help them identify these clues in the AR modules. Figure 3.4 shows the course through the game each of the three roles took.

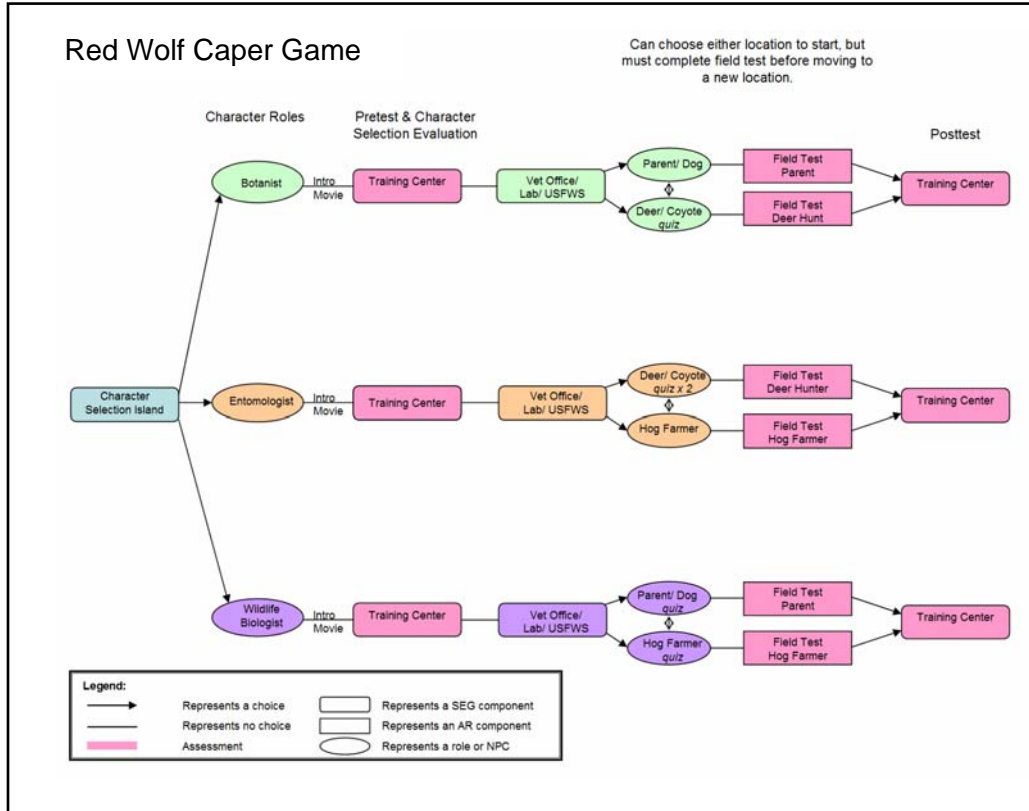


Figure 3.4. Red Wolf Caper game map demonstrates how students moved through the game and where they encountered assessments.

The first three sections of the game, character selection island, the training center, and the veterinary office and lab, were all created in Adventure Lab. Figure 3.5 provides a screenshot of each of these different areas in Adventure Lab as well as the forest, hog farm, and neighborhood. The game started on an island where the student could learn more about the three role choices. Once they decided on the role they wanted to play, study participants were ported to the training center where they watched an opening movie. The movie gave the

study participants an introduction to the problem and some of the history behind the Red Wolf Reintroduction Project in North Carolina. The study participants then took a pretest based upon their role (Appendix B). After the pretest, participants were given further information about the Red Wolf Reintroduction Project through books found in the game and through websites they could access through the game. The websites included United States Fish and Wildlife Service (USFWS) website on the project, the USFWS team's blog, the Red Wolf Coalition, Field Trip Earth (a website run by the NC Zoological Society), and Defenders of Wildlife's website on red wolves. Each role also was given training on common species they may find in the local geographic area. The next Adventure Lab area the study participants visited was the veterinary office and lab, where they were given the final details of the mission and tools to help them during their investigation. At the veterinary office the study participants were able to interview the veterinarian, who was caring for a red wolf, the lab technicians running tests on the red wolf, and the USFWS biologist, who gave them more details about the different locations within Adventure Lab and in the MITAR world to visit. The veterinarian described the situation with the red wolf that was currently in his care. He also explained the ingredients he needed to create an antidote. The USFWS biologist tells the participant that they are busy right now checking on the status of all the red wolves in the program and did not have the time to conduct the investigation himself. Both the veterinarian and the USFWS biologist mentioned several people that the participant may want to interview. One of the lab technicians explained the results from the necropsy done on one of the red wolves that had died at an earlier date. The participant was given the responsibility to deliver a blood sample to the other lab technician. That technician analyzed the blood sample

and tells the participant more about the poison. Finally, there were books in the vet's office providing information on how to use field guides and characteristics to look for when identifying a species.



Figure 3.5. Screenshots of each of the six areas in Adventure Lab; (a) character selection island, (b) training center, (c) veterinary office, (d) coyote trapper in the forest, (e) hog farmer, and (f) the concerned parent in the neighborhood.

After the veterinary office the study participants could chose one of two locations to visit. Depending on the role they had different options. The entomologist was able to choose between the hog farm and the forest with the coyote trapper and the deer hunter. The botanist

was able to choose between the concerned parent and the forest. The wildlife biologist was able to choose between the concerned parent and the hog farm.

Each location occurred in both Adventure Lab and MITAR and had at least one NPC to interview (Table 3.5). The NPCs that each role interviewed are shown in the game map (Figure 3.4). At each location there was a NPC who shared their concerns about the situation and provided additional clues that related to the role the student chose. A brief description for each NPC's story is given below:

- Kristen Jones, deer hunter – Kristen was upset because she thought the deer population was being decreased with the reintroduction of the red wolves. She hunts deer to provide food for a battered women's shelter that she runs.
- Ronald White, the coyote trapper – Ronald used to trap coyotes for the USFWS, but someone started spreading rumors that he was trapping both coyotes and red wolves. According to the rumor he was selling the red wolves on the black market.
- Sharon Harper, concerned parent – Sharon was concerned that the red wolves will harm her children. She found tracks in her backyard that a neighbor told her were red wolf tracks.
- Martha Davenport, dog owner – Martha was concerned that the red wolves will eat her dog. She read an article about gray wolves out west eating people's pets.
- Jerry Farrand, the hog farmer – Jerry swore that a red wolf killed one of his prized sows. The USFWS service investigated and determined that it was domestic dogs that killed his sow, but he does not believe them. He shot a coyote thinking it was a red wolf.

In addition, one to two NPCs asked quiz questions for each role. The quizzes were not meant to be a formal assessment, but a chance to practice using the field guides and information they had been provided in the game. The intention was to have two quizzes for each role, but as the game was redesigned from the pilot test version to the version used in this study, the botanist's second question was unintentionally omitted. An example of a quiz question was, Kristen Jones "Before you take your field test can you help me identify this plant. I noticed the deer browsing on it a lot." A picture of the plant was then opened in their web browser (Fig. 3.6) and they could use the information provided earlier in the game to answer the question. If they answered the quiz question correctly the study participants were given a clue to help them in the field test for that module. If the botanist correctly identified greenbrier (*Smilax sp.*) in the previous example, they were given the hint "the fruit of this plant was ground to make flour", which would hopefully help them identify the white oak (*Quercus alba*) tree in the field test.

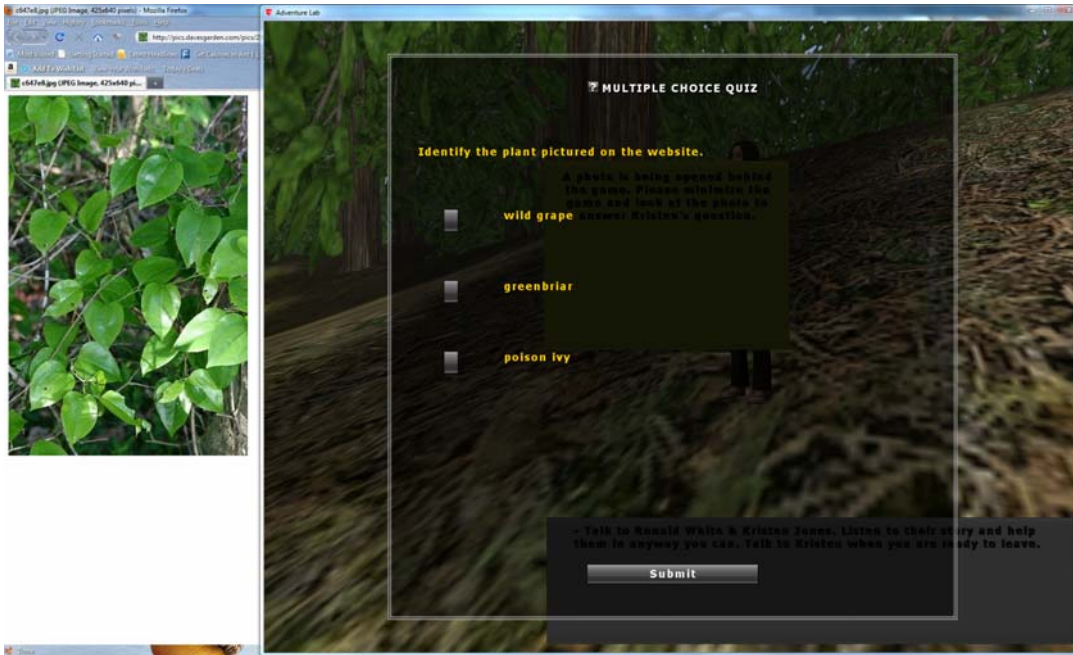


Figure 3.6. An example of a quiz question. The screenshot shows the question in Adventure Lab and the plant image that was opened in the student's web browser.

Table 3.5

Location of NPCs and Quizzes

Location	NPC	Quiz
Forest	Ronald White - coyote trapper	Entomologist
	Kristen Jones - deer hunter	Entomologist, Botanist
Hog Farm	Jerry Farrand - hog farmer	Wildlife Biologist
Neighborhood	Sharon Harper - concerned parent	Wildlife Biologist
	Martha Davenport - dog owner	

At each of the two locations the study participants visited in Adventure Lab, there was an outdoors field test. Once a field test was encountered the participant was supposed to go no further in the game until the activity was completed. A field test involved using AR to find an object placed or naturally occurring that the study participants must correctly identify using a field guide. They were told the location of the object, then using the ASUS Mypal Pocket PC A696 with built-in GPS they navigated to the location. Once at the location, the PDA triggered the NPC the participant was supposed to be helping and was asked for a code. The code was given to them in Adventure Lab. Once the study participants input the code, they were shown a picture of exact location of the object. Study participants then used the image to find their object. Upon finding the object they used field guides to identify it. Each role used a different field guide; botanists used *A Pocket Naturalist Guide: Trees*, entomologists used *A Pocket Naturalist Guide: Bugs & Slugs*, and the wildlife biologists used *A Falcon Guide: Scats and Tracks of the Southeast*. The field guides were selected because of their layout, portability, ease of use, and content. Each species in the field guide was given a number. When the participant believed they had correctly identified their object they could input the number from the field guide into the PDA to check their answer. If correct, they were told to return to the Alumni Center to continue the game.

As an example of how a field test worked, a student playing the role of the wildlife biologist had just visited the concerned parent in the Adventure Lab portion of the game, and was asked to identify the tracks found in her backyard. The student was then told to use the AR to locate the tracks. Using the PDA the student navigated to the “concerned parent” location on the map (see Figure 3.1). Once at the location Sharon Harper, the concerned

parent, was triggered and asked them again to identify the tracks in her yard (Fig. 3.7). The participant entered the code (i.e., 375) that Sharon Harper gave in Adventure Lab. Entering the correct code triggered a picture of where the tracks were located, which the participant had to locate on the ground. The study participant was shown a picture of the track location because the PDA was only programmed for a general area and not an exact location because of the MITAR software. GPS coordinates could not be entered into MITAR to provide a specific location. Instead locations were placed on the aerial photograph through heads-up digitizing. Large errors in satellite accuracy may have been possible, so the student would have to search for the track even if the PDA could have been programmed for an exact location. The biologist (study participant) identified the track using the provided field guide. In this particular case, it was a bobcat (*Felis rufus*) track; so the code number 43 was entered, which was found in the provided field guide. If identified correctly and the proper code was entered, the study participant was told to continue with the Adventure Lab portion of the game.

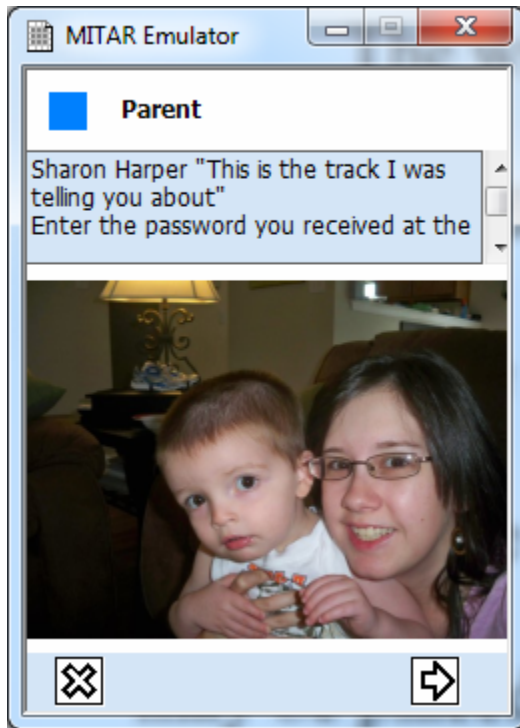


Figure 3.7. An example of an NPC being triggered at the real world location.

The wildlife biologist was asked to identify a set of bobcat tracks and turkey (*Meleagris gallopavo*) scat. The tracks were placed in mud at the concerned parent location using rubber replicas. The scat was a rubber replica also. The botanist was asked to identify two trees, sweetgum (*Liquidambar styraciflua*) and white oak (*Quercus alba*). The entomologist was asked to identify two invertebrates, harvestmen or daddy longlegs (*Leiobunum vittatum*), and termites (Order Isoptera). The invertebrates were captured prior to the study participants' arrival, placed in a clear magnifying "bug" box, and hidden at the appropriate location. All objects were placed or verified before each session.

At the end of each module the student received a report from the other two roles explaining what they found at that particular location. Once study participants had enough

information to create a hypothesis they returned to the training center. The study participants then completed the posttest, which was identical to the pretest and watched the closing movie that showed an unidentifiable culprit being arrested. The study participants were given a data sheet (Appendix E) at the beginning of the session on which to write their hypothesis and supporting evidence for the wildlife law enforcement to review. The game was not designed with a specific suspect in mind; instead, it was designed to allow the study participants to draw their own conclusions using their supporting evidence.

Instrumentation

All participants were asked to complete a knowledge assessment (Appendix B), background survey (Appendix C), Serious Educational Game Rubric (SEGR) (Annetta, Lamb, & Stone, in press 2010; Appendix D), hypothesis sheet (Appendix E), and role selection survey (Appendix F) as part of the data collection process for this study. Eighty-one background surveys, SEGR, and hypothesis sheets were collected from the study participants. Only 69 sets of pretests/posttests and role selection surveys were completed. These five instruments along with 23 interviews were used to answer the three research questions. Each instrument is described in detail below.

Knowledge Assessment. The knowledge assessment test, which was a portion of the pretests and posttests, was the only one of the four instruments that was based on the role the student chose to play. Each role had a pretest/posttest (Appendix B) designed to measure the student's knowledge in that topic area. The test was made of five multiple choice questions, four questions related to their particular topic and one general question about red wolf reintroduction. The botanist's questions included parts of a leaf, leaf identification, historical

uses of plants, and defining invasive species. The entomologist's questions included characteristics of an insect, classifying invertebrates, communication techniques, and organ identification. The wildlife biologist's questions included defining necropsy, identifying tracks, identifying a red wolf, and hybridization issues. The fifth question on each test was about some of the common concerns associated with the red wolf reintroduction project. The pretest and posttest for each role was identical, so each student took the assessment twice. The assessments were uploaded into *SurveyMonkey*, and as part of the game design, the survey were triggered in the game world and loaded in a web browser.

The pretests were created by the researcher who was a former wildlife educator for the NC Wildlife Resources Commission. In addition, the information in the tests was validated by a Certified Wildlife Biologist[®] from the NC Wildlife Resources Commission.

Background Survey. The background survey (Appendix C) included three sections; the first section asked basic demographic information, the second section asked about weekly and monthly activities, and the third section asked about video game preferences. The weekly activity table asked study participants to identify in which of 13 activities they participated and how many hours a week they participated in them. These activities included a combination of indoor ($n = 8$), outdoor ($n = 2$) activities as well as ones that may include both ($n = 3$; e.g., Boy or Girl Scouts). The activities also included technology ($n = 4$) and non-technology ($n = 9$) involved activities. The monthly activity table asked student to identify in which of 10 activities they participated and how many times a month. Again it included a combination of indoor ($n = 5$) and outdoor activities ($n = 5$). There were three

activities that specifically involved technology. Finally, study participants were asked which of 12 types of video games they played and to rank their top three categories.

SEGR. The Serious Educational Game Rubric (Appendix D) was created and tested by Annetta et al. (in press 2010). It was made up of 15 categories: *prologue, tutorial/practice level, interactive, feedback, identity, immersion, pleasurable frustration, manipulation, increasing complexity, rules, informed learning, learning, pedagogical effectiveness, reading efficiency, and communication*. Each category was scored on a 0 to 2 point scale. Only 14 of the 15 categories were used in this project. *Communication* was for multiplayer games and did not apply to Red Wolf Caper.

Hypothesis Sheet. The hypothesis sheet (Appendix E) was a simple datasheet where study participants could take notes as they played the game then present their hypothesis of who was poisoning the red wolves and why. They were asked to back their hypothesis with supporting evidence. Finally, the study participants were asked to write a letter to a local judge supporting the red wolf reintroduction project. Study participants were asked to write a minimum of three sentences.

Role Selection Survey. This survey was merged with the pretests and posttests (Appendix F). Soon after the study participants picked their role they were asked to explain why they chose that particular role. This served as the first question of the pretest followed by the knowledge assessment questions. At the end of the game they were asked if the role was what they expected, if they were interested in learning more about that particular branch of science, and how the role was similar or different from what they expected. These three open-ended questions were the first three questions of the posttest. In addition to the role

selection questions, and as part of their posttest, the study participants also were asked if they finished the game.

Interviews

Eighteen study participants were randomly selected for interviews. Each participant was given a student number at the beginning of the session. Three numbers from each session were randomly chosen using the random number generator on *Random.org*. The study participants marked for interviews had an asterisk (*) on the sticker next to their student number. In addition, to the 18 randomly selected study participants, five more study participants were asked to participate in an interview because the majority of the interviews were from participants playing the wildlife biologist role. To get input from the other two roles, study participants playing an entomologist or botanist on the last day of testing were targeted for interviews. After the student had completed the game, they were asked to participate in an interview. The interview was made up of seven questions (Appendix G). The interview questions asked study participants to describe their experience with the game, what they thought of the AR portion, their favorite and least favorite parts of the game, the next step for the game, and finally if they liked to spend time outdoors.

Pilot Test

A pilot test was conducted on the morning of June 14, 2010. Fourteen middle school students participated. The group was made up of 11 males and three females. The group was predominantly Caucasian with three minority representatives. Four grades, fifth ($n = 1$), sixth ($n = 4$), seventh ($n = 7$), and eighth ($n = 2$) were represented in the sample.

The main focus of the pilot study was to improve Red Wolf Caper and fix any problems before the main study, as well as determine exactly how the sessions should be run. Several issues were encountered during the pilot test including problems with the game, Internet connection, and time management. Problems in the game included players' inability to understand how to move, in-game text not being displayed long enough to read and comprehend, and lack of guidance of what the players were suppose to be accomplishing/game goals. On the field tests, the pictures identifying the location of the object did not display. As problems arose study participants were encouraged to write notes on their student observation sheets or let one of the staff members know.

As study participants played the game they did not realize that the Internet was supposed to be opening at different points. When they saw *YouTube* or *SurveyMonkey* open, they closed their browser and continued playing the game. In other cases, because of updates to the Internet browser the previous day, the browser tried to install updated toolbars instead of opening the appropriate website. An Internet connection could not be established on a couple of computers even though they had been tested previously.

Time management was an issue. Originally, it was planned to send study participants out on field tests as they encountered them in the game. As study participants were ready, they were sent with a chaperone either by themselves or in groups of 2 or 3. It quickly became an issue that with three chaperones and 14 study participants that many study participants had to wait for long periods of time to be able to go out on a field test. The version of the game being tested in the pilot study consisted of three field tests instead of two. Most study participants only completed two field tests before running out of time.

Because of field tests taking longer than planned, no interviews were conducted and the original idea of a group design session became small group sessions as study participants waited for chaperones or finished the game.

Several changes were made after the pilot test to both the game and the format of the sessions. Field notes, SEGR (Table 3.6), written comments, and the design session notes (Table 3.7) were used to guide improvement of the game. The total SEGR score ranged from 14 to 24 with 28 being the highest possible score. The SEGR showed that all areas of the game, except *interaction*, could use improvement. The design session notes included both comments the study participants wrote in their notes and what they told the researcher during the design sessions. Using the information provided by the study participants, the game was improved/fixed before the main study.

To fix the issues study participants were having with moving in the game, more detailed instructions were provided at the beginning of the game and a few objects like the couches in the veterinary office were replaced. Study participants were jumping into the center of the couches and getting stuck. The only way to fix this at the time of the pilot test was to restart the veterinary office level. The next issue was the in-game dialogue boxes did not display all of the text. This was fixed by resizing all the text boxes in the game. The game was designed on a 17" monitor, but was played on a 15" monitor. Because of this, there was a difference in the way the game was displayed, which resulted in most of the dialogues in the game being cut off. The time that the dialogue was displayed was also increased. To provide better guidance for the study participants, more detailed mission descriptions were provided as well as some character dialogues changed to provide more detail or guidance. One example of this

was that study participants were having difficulty finding the blood sample they were supposed to give to the lab technician. There was a blood sample already on the lab technician's counter and the study participants thought it was supposed to be that sample. The blood sample in the lab was changed to a urine sample to prevent confusion. In addition, the blood sample in the doctor's area was increased in size and the doctor walked over to it when he mentioned taking the sample to the lab.

Table 3.6

Pilot Test SEGR Mean and Standard Deviation

Category	Mean	Standard Deviation
Prologue	1.38	0.65
Tutorial/ practice level	0.92	0.64
Interactive	2	0
Feedback	1.54	0.52
Identity	0.76	0.83
Immersion	1.23	0.60
Pleasurable frustration	0.85	0.80
Manipulation	1.23	0.60
Increasing Complexity	1	0.82
Rules	0.85	0.69
Informed Learning	1.62	0.51
Learning	1.70	0.48
Pedagogical Effectiveness	1.31	0.63
Read Efficiency	1.23	0.60
Total	17.62	3.10

Table 3.7

Pilot Test Design Session Notes

Student Specific Comments:

- 61401 – Suddenly switched to a different passage when I clicked on the bug researcher. Botanist, bug researcher, and wildlife researcher stopped in mid sentence then carried on to another sentence. Everyone did not finish their sentence. A lot of times I did not know what to do.
 - 61402 – Sometimes, the person who is talking doesn't finish his/her sentence.
 - 61404 – Every now and then skips word panels. Skips field investigation hints. No picture with question. (wildlife biologist)
 - 61405 – Did Mr. Farrand shoot a red wolf? No picture
 - 61408 – Text hard to navigate. Bookcase not fully rendered.
 - 61409 – The tortoise is flying. The boxes don't have an the dialogue.
 - 61410 – All dialogue switched weird. People stand still. Why don't they walk around?
 - 61412 – You can enter some houses through the wall. You can fall through the floor.
 - 61413 – If you ride on turtle it floats. Dialogue box.
 - 61415 – Press N for object names. Step on grass and go up. Flying turtle I go through turtle.
-

Table 3.7 cont.

General Comments:

- dialogue boxes
- couch in vet office, switch – study participants getting stuck in center
- hunter/coyote trapper (Internet) picture not popping up
- test-tubes hard to find
- more details in missions – overhead map if possible
- check PDA locations
- Characters in neighborhood bouncing
- Dialogue box time too long for short dialogue & too short for long dialogue
- Check raccoon track
- Change the word debrief – study participants don't understand the word.

Regarding the web browser opening during the game, a warning box was added in-world each time the game accessed the Internet (Fig. 3.8). The box warned the study participants that it was opening something in the Internet browser and to minimize the game and look at the information that was being provided within the web browser. All computers were double checked to make sure they were able to access the Internet.

The problems with the field tests or augmented reality portions, specifically time management and the pictures not displaying, were also addressed. The pictures were fixed by decreasing the file size. The files were simply too large for the PDAs to handle. The time

management issue was handled by taking study participants in larger groups to the real world areas, which meant the study participants, had to wait for a group to go out. In the long run the wait was shorter because normally the study participants only had to wait the first time to go out instead of waiting for every single field investigation. One of the GPS locations was also cut from the game. Instead of doing three field tests, study participants were required to do two. The study participants were asked during the design session which of the four locations they would like to see cut. Study participants responded coyote trapper ($n = 5$), hog farmer ($n = 3$), and naturalist ($n = 1$). No one recommended that the concerned parent location be cut. Ultimately the naturalist was cut because it was used only by the botanist and entomologist, the least popular roles. In addition, only one student went to that location during the pilot test and he recommended that it was cut. By cutting that location, it reduced the botanist and entomologist site visits to two locations. The coyote trapper was cut from the wildlife biologist location based on study participants' recommendations; leaving each role with only two field tests.

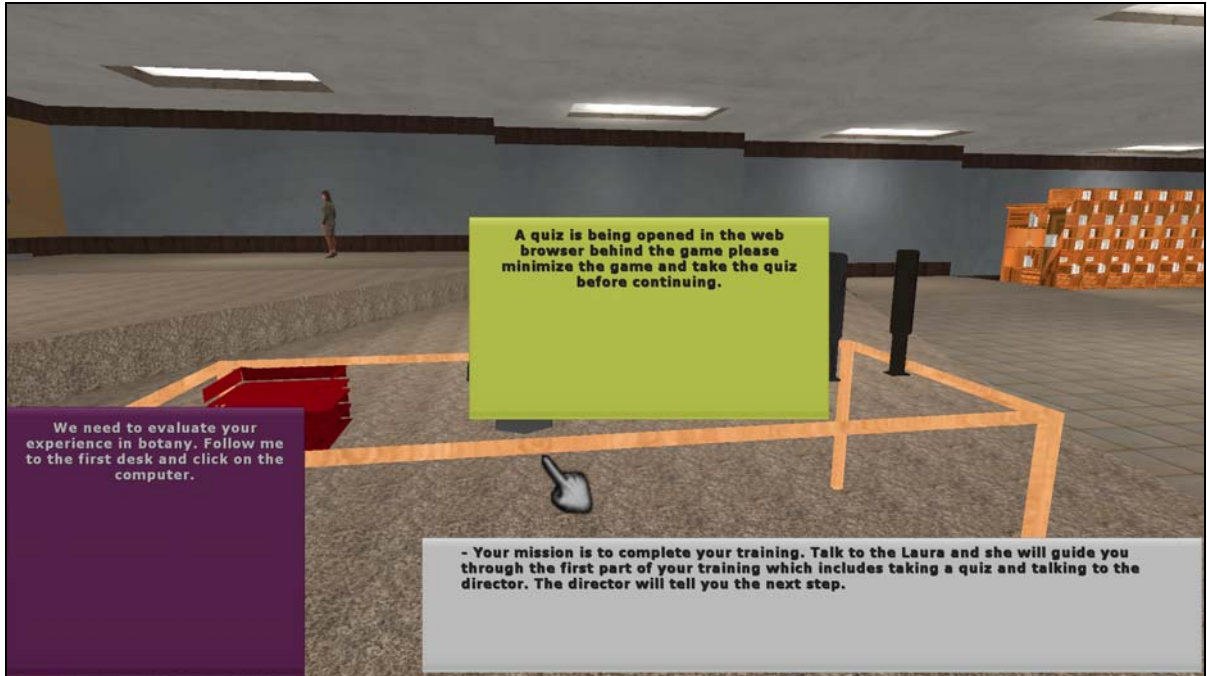


Figure 3.8. Example of a warning box being displayed before a quiz was accessed on *SurveyMonkey*.

During the pilot test, only six complete pretest/posttests were collected with the role selection information due to the problems with the Internet and study participants not understanding that the Internet browser was supposed to open. Because of this, these data were not used for improving the game.

The field note sheets, which included the student's hypothesis, evidence and letter to the judge, were examined to create categories for the main study. Five categories were created from the hypotheses:

- *Direct* – the student accused a specific character in their hypothesis.
 - Example – “The farmer is poisoning the red wolves, because they attacked his pigs.”

- *All encompassing* – the student named several individuals or groups in their hypothesis.
 - Example – “The humans with a common chemical found on farms or houses.”
- *Group* – the student accused a group that the character in the game represented instead of the specific individual.
 - Example – “I think livestock owners are because they do not like wolves because they think they are dangerous to their livestock.”
- *Indirect* – the individual didn’t do it on purpose, it was an accident.
 - Example – “I think the pesticides are poisoning the red wolves prey, because then when the red wolves ate the animal that was poisoned, they would be poisoned.”
- *No Accusation* – the student did not name anyone.

Three categories were created for the study participants’ supporting evidence:

- *Circumstantial* – evidence would not hold up in court
 - Example – Chemicals around his farm.
- *Moderate* – the student put some thought into their evidence
 - Example – Red Wolves’ prey eat fruit and plants from farms. Pesticides run off in rivers, where red wolves drink them. Pesticides poison animals.
- *Thorough* – evidence would hold up in court
 - No example available.

Using these categories there were 8 *direct*, one *indirect*, one *all encompassing*, two *groups*, and two left blank. The evidence was *circumstantial* ($n = 9$), *moderate* ($n = 2$), and left blank ($n = 3$). Finally, the letters to the judge were viewed and three categories emerged:

- *Food Chain* – the importance of the food chain was mentioned in the letter.
 - Example – “Red wolves must be reintroduced to this area. They are at the top of the food chain so they would help keep rabbits, raccoons, and rodents population down. They really are amazing animals.”
- *Ecosystem* – the letter either mentioned keeping the balance of the ecosystem or that the red wolves were an endangered species.
 - Example – “It is important that red wolves are reintroduced because it is important that every animal is in their area that they should be so the ecosystem is in balance.”
- *Frivolous response* – was categorized as any response that did not relate to the task.
 - Example – “lower chemical strength”

Some letters fell into more than one category. Six letters discussed the *food chain*, 5 mentioned the *ecosystem*, three provided a *frivolous response*, and two were left blank. It is interesting that the study participants really picked up on the food chain and the role that the red wolves play in the ecosystem. These particular points were only directly mentioned in the opening video and in one brief paragraph they were asked to read.

Protocol and Data Analysis

This section is divided by research question. Each research question's needs are addressed including data that were collected, instrumentation used, and the data analysis methods (Table 3.8). This was a mixed methods project and some of the research questions used quantitative data while others used qualitative data or a combination of both.

Table 3.8

Research Design Matrix

Research Question	Data Sources	Data Analysis
1. Do mSEGs affect students' understanding of environmental education concepts?	<ul style="list-style-type: none"> • Pre-/ post-knowledge assessment • Student's hypotheses/Evidence • Letters to Judge 	<ul style="list-style-type: none"> • Paired Student's t-test • One-way ANOVA • Qualitative Coding
2. Which role do the students choose and what is their reasoning behind choosing that particular role?	<ul style="list-style-type: none"> • Role selection survey • Interviews 	<ul style="list-style-type: none"> • Qualitative Coding
3. How would students improve the Red Wolf Caper mSEG?	<ul style="list-style-type: none"> • SEGR (Annetta, et al., in press 2010) • Design session notes • Written comments • Interviews 	<ul style="list-style-type: none"> • Scoring of the SEGR • Qualitative Coding

Question 1: Do mSEGs affect students' understanding of environmental education concepts? Question 1 focused on collecting, evaluating, and developing explanations for data the study participants collected in the mSEG. The second part of the question examined the knowledge of environmental systems and biological and social implications for the reintroduction of a species. The guidelines for each of these parts, as described in the *Excellence in Environmental Education Guidelines for Learning (Pre K – 12)* (Simmons, 2004), are given in more detail below:

- Collecting information
 - Assess, choose, and synthesize materials from resources such as aerial photographs, topographic maps, and satellite images; library and museum collections, historical documents, and eyewitness accounts, computerized databases and spreadsheet; the Internet; and government records.
 - Collect firsthand information about their own community using field study skills (Simmons, 2004, p. 31).
- Evaluating accuracy and reliability
 - Identify factors that affect the credibility of information, including assumptions and procedures used to create it; the social, political, and economic context in which the information was created; and potential bias due to omission, suppression, or invention of factual information.

- Examine evidence, identify faulty reasoning, and apply other basic logic and reasoning skills in evaluating information sources (Simmons, 2004, p. 31).
- Drawing Conclusions and developing explanations
 - Consider the possible relationships among two or more variables.
 - Propose explanations based on what they observed or learned through research, selecting which evidence to use, and accounting for discrepancies. Synthesize and interpret information from a range of sources (Simmons, 2004, p. 33).
- Systems and connections
 - Describe and give examples of producer/consumer, predator/prey, and parasite/host relationships (Simmons, 2004, p. 36).
- Individuals and groups
 - Explain how group membership and shared values, beliefs, and assumptions can influence individuals, impel different reactions to physical and social environments and changes, and cause social change (Simmons, 2004, pp. 37-38).
 - Identify and critique instances of stereotyping based on group affiliation (Simmons, 2004, p. 38).

The systems and connections part of the question was partially measured through the pretest and posttest knowledge assessments given to the study participants as part of the

game. The pretest and posttest scores were analyzed using a paired samples T-test. A one-way ANOVA was used to check for gender effects on the pretest/posttest scores.

The study participants' hypothesis and evidence sections of the hypothesis sheets were used to measure the collection, evaluation, the conclusions drawn from data, and the social implications. The hypotheses were coded using the categories established during the pilot test. The researcher and two staff members coded the sheets to ensure inter-rater reliability. Inter-rater reliability was calculated by summing the total number of items the raters agreed upon and dividing it by the total number of items. All the categories for the hypothesis and evidence were the same as that for the pilot test. The hypothesis and evidence reliability scores were 91.36% and 87.65%, respectively, which provided enough reliability to use the data to answer this question.

The letters to the judge were used to measure all parts of question 1. In reviewing the letters to the judge, it became obvious that additional categories were required. Two additional categories were added:

- *Computer game*: Instead of writing a letter to the judge about the red wolf reintroduction project, some study participants wrote a letter about the computer game.
 - Example: "It is important because red wolves are helpful it's a cycle. This program has really taught me a lot. I would like to do this type of program at my school. This program could be very educational for kids of all ages."
- *Anthropomorphism* – The student compared what was happening to the red wolves to humans.

- Example: “Dear local judge, the red wolf has as much importance as the human being because they eat, survive, populate and evaluate just as people do. If you kill red wolves its like murder. Red wolves lives are just as valuable as ours.”

Some of the letters were coded for more than one category. The inter-rate reliability score for the letters was 90.12%.

Question 2: Which role do the students choose and what is their reasoning behind choosing that particular role? The study participants were asked to fill out a short online questionnaire asking them which role they selected and why. Each role was examined individually and categories were established for that role. Whenever possible, the same categories were used across roles. The study participants were asked about their experience as that role, if they would like to learn more about that particular field, and if the role was what they expected. Each question was examined for positive and negative responses and then placed into categories related to the study participants’ response. Whenever possible, the categories from the pretest were used. In addition, the 23 study participants interviewed were asked what role they chose and why. Their answers were compared to the answers they gave in the pretest.

Question 3: How would students improve the Red Wolf Caper mSEG? After playing the game, study participants evaluated Red Wolf Caper using SEGR (Annetta, et al., in press 2010) and participated in a design session. In addition, 23 study participants participated in interviews that asked them to describe their game experience, the next step in the game they would like to see, and their least favorite and favorite part of the game. Three

experts in SEGs games played and evaluated the game using the SEGR to add validity to the student's responses. Means, standard deviations and Kappa Scores were calculated for each of the 14 categories and the total SEGR score. A Kappa Score measures the level of agreement between responses. The SEGR information will be used to improve the overall game, whereas the design information will be examined for common suggestions in changes and additions to include in the updated the mSEG version of the game and the future all-AR version of the game. This is part of the design based approach this study has taken.

The design sessions were held in small groups to give study participants more of a chance to speak out. Study participants were pulled into a design session as they waited for chaperones to do the field tests and after they completed the game. They were encouraged to give all their ideas of how to fix problems found in the game and to suggest changes or additions to Red Wolf Caper. A staff member would go from table to table to talk with each group of study participants and get their opinions on the game and recording this information on a flip chart so that participants could see what was being recorded. In addition, study participants were encouraged to write comments or problems they encountered on the notes section of their observation sheets.

This chapter described the overall process for data collection and analysis for this study. In addition, it described the pilot study results and the changes that occurred to the game as a result of the pilot test. The next chapter will describe in detail the results of this study.

CHAPTER 4

Results

Overview

The results for the three research questions are presented in this chapter. The quantitative results for each question are presented first in each section followed by the qualitative.

Question 1: Do mSEGS affect student's understanding of environmental education concepts?

Pretest/Posttest. Sixty-nine completed sets of pretest/posttest were analyzed. The distributions of the pretest's final score ($\mu = 40.53$, $SD = 20.26$) and posttest's final score ($\mu = 55.49$, $SD = 24.66$) showed that the average score increased between tests. A t-test conducted on the final scores of the pretest and posttest ($p = 0.000046$) showed there was a highly significant difference. There was no gender effect found on either the pretest ($F = 0.11$, $p = 0.74$, $df = 1$) or posttest ($F = 0.05$, $p = 0.83$, $df = 1$).

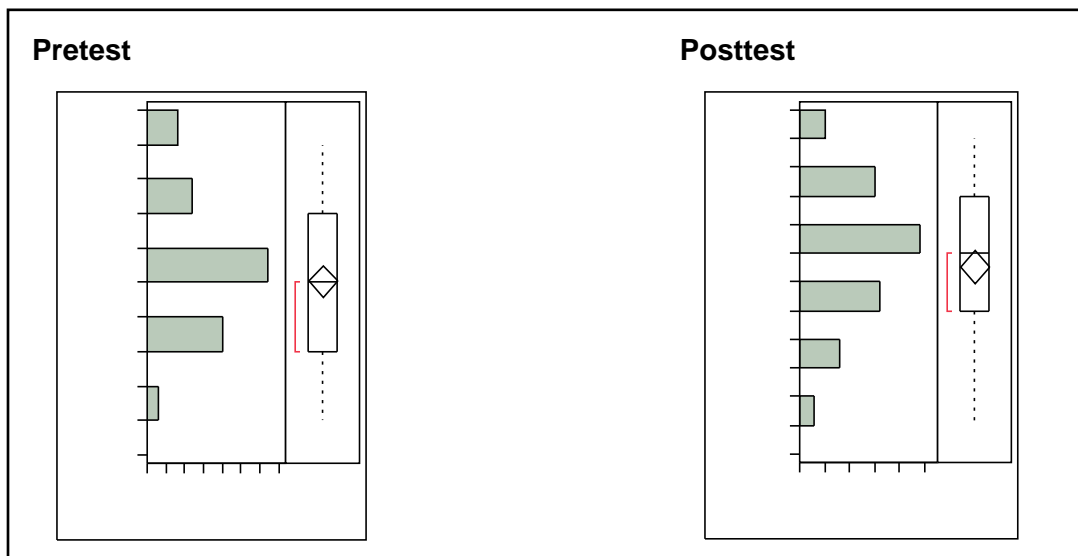


Figure 4.1. Pretest and Posttest Distributions

Study Participants' Hypothesis and Evidence. The hypothesis and evidence section of the student observation sheet was where the study participants recorded who they thought committed the crime and the evidence they had to support their accusation. The study participants felt overwhelmingly that Jerry Farrand, the hog farmer, was the culprit ($n = 54$). The other characters received much fewer votes: the hunter ($n = 9$), the pet owner ($n = 8$), the parent ($n = 6$), and the trapper ($n = 0$). Seven study participants named more than one culprit and 13 others named either another character in the game that was not supposed to be a suspect (e.g., the director, the veterinarian, and scientist) or had a completely different theory of what was happening. Examining the categories that were created for the hypothesis statement, 50 were *directly* blaming someone, eight named a *group* instead of an individual, seven named several characters or were *all encompassing* in nature, four *indirectly* accused a group or individual, and three did not accuse anyone.

The results suggested 53 used a *moderate* amount of evidence to back up their hypothesis, while 10 study participants provided only *circumstantial* evidence. *Circumstantial* was defined in the pilot test as evidence that would not hold up in court and *moderate* was defined as the study participant had put some thought into their evidence. Eight study participants did not provide any evidence or they talked about parts of the game instead of providing evidence. The raters could not agree on what was considered *thorough* evidence or evidence that would hold up in court, therefore there was no one in the *thorough* category (Table 4.1). The *thorough* classification was defined as evidence that would hold up in court.

Table 4.1

“Thorough” Category Comparison between Raters.

Evidence	Rater 1	Rater 2	Rater 3
He is afraid his hogs will get eaten. He is the only one who is against red wolves. He had weird chemicals around the barn. He had pesticide problems.	Circumstantial	Thorough	Moderate
Same chemicals in her shed as poisons in animals. Poisons next to dog treats.	Moderate	Thorough	Thorough
It’s a poison. Poison acts like pesticide. The trapper only got coyotes. The hunter was angry but no wolf was shot.	Moderate	Thorough	Moderate
Shot coyote thinking it was a red fox.	Moderate	Moderate	Thorough
Said he put chemicals in his plants. Picture showed wolf dead with no bullets in it.	Moderate	Moderate	Thorough

Letter to Judge. The letter to the judge kept many of the same themes that the pilot study had suggested: balance of ecosystem, red wolves keep prey species in control, and/or that the red wolves were an endangered species, therefore should be protected. Forty-two study participants mentioned the *ecosystem*, 25 mentioned the *food chain*, six wrote *frivolous responses*, five wrote about the *computer game*, and three focused on *anthropomorphism*. *Frivolous responses* were defined in the pilot study as answers that did not relate to the task

assigned. Nine of the letters fell into multiple categories: most common were *ecosystem* and *food chain*. An example of one letter that fell into the *food chain*, *ecosystem*, and *anthropomorphism* categories was: “Red wolves are important to many ecosystems and many food chains will be in chaos if they do go extinct. But also red wolves are living beings. Would it be okay with you if our species started going extinct?”

The letters once again showed that study participants picked up on elements in the game that were only briefly portrayed, such as the food chain. This particular element was only mentioned in the opening video. The study participants also made a link to red wolves helping keep the deer populations lowered from the complaints of the deer hunter, Kristen Jones. Although, this is not completely correct, because red wolves do not eat enough deer to keep the population in check, it does show that study participants understand that a predator species can help control its prey species.

“The red wolf is an important creature because it helps keep other animals, like deer, at a good rate. Without these wolves the deer population will go up and we will lose more plant life. This will throw the natural balance out of order.”

Question 2: Which role do the students choose and what is their reasoning behind choosing that particular role?

The study participants selected one of three roles to play the game, a wildlife biologist ($n = 64$), an entomologist ($n = 10$), and a botanist ($n = 6$). In all but one session, there was a combination of at least two of the roles represented. In the Tuesday afternoon session, the entire group chose to be a wildlife biologist. Even though it was not reflected in

any of the student comments or interviews, friendship also seemed to play a role in the study participants' selection. If study participants came with a friend, in most cases, they played the same role.

Role Selection Survey. Study participants were asked as part of the pretest why they selected their particular role. All the study participants who chose to be a botanist said they thought that plants were interesting or that they understood that plants played an important part in an ecosystem. The study participants who chose to be entomologist had three different reasons for choosing the role. Two study participants wanted to learn more about insects or the role insects played in the game. Three study participants had previous positive experiences with entomology. Five study participants just liked insects or found them interesting. The wildlife biologist, being the largest group, had five categories into which their responses fell: liked animals ($n = 24$), interested in learning more about the wildlife biologist role ($n = 21$), better than the alternatives ($n = 12$), sounded fun or exciting ($n = 6$), and misunderstood the role ($n = 1$) (Table 4.2).

Table 4.2

Examples of Student Comments for Choosing to be a Wildlife Biologist.

Reason for Choosing Wildlife Biologist	Examples of Student Comments
Like Animals	<ul style="list-style-type: none"> • I like animals • I love wild animals • Because animals are cute and I enjoy learning about them. • Because I like work with animals.
Wildlife Biologist as a Role	<ul style="list-style-type: none"> • They have a variety of skills. • I chose to be a wildlife biologist because I thought I could learn more about the real problem. • I have always wanted to learn more about animals in their home and how they survive in nature.
Better than Alternatives	<ul style="list-style-type: none"> • Because I thought it sounded better than the other 2 jobs. • I think that a wildlife biologist is more interesting than an entomologist or a botanist. • Because the other options are boring.
Sounded Fun or exciting	<ul style="list-style-type: none"> • It looked like the most fun and interesting role to play. • Because it seemed kind of fun.
Misunderstood the Role	<ul style="list-style-type: none"> • I like plants and it would be good to do good things with plants.

After the study participants completed the game, they were asked to explain their experience in that role in the game, if they were interested in learning more about that particular field, and how the role was different from what they expected. The botanists

described their experience as educational ($n = 3$), hard ($n = 1$), unique ($n = 1$), and misunderstood ($n = 1$).

- Educational – “I learned about new plants. I also learned how they are useful.”
- Hard – “It is sort of hard being a botanist. You have to know all sorts of plants. It is also fun!”
- Unique – “It was a very interesting role in the game. Not one of the other kids picked the role.”
- Misunderstood – “I was a wildlife biologist.”

All the botanists mentioned that they would like to learn more about botany. When asked how the role was different from what they expected, two study participants said it was not different, one said they didn't know what a botanist was, one thought botany was only about flowers, and one thought they would only be identifying plants virtually. The misunderstood student said that they did not do anything botany related.

The entomologists described their experience as educational ($n = 8$) or interesting/cool ($n = 2$).

- Educational – “I learned about how the insects communicate with each other and how to identify them.”
- Interesting/Cool – “It was interesting.”

Seven of the study participants were interested in learning more about entomology, while three said they were not interested in learning more about the field. One of the study participants not interested in learning more said “Not really, but my dad is an entomologist so I thought it would be interesting to learn something about insects.” Those making positive

responses made comments about liking insects or diversity of insects, “Yes, I think I would like to learn more about entomology. It is interesting because there are many different kinds of insects.” Only one student felt the role was not different from what they expected. The other study participants did not expect to be looking for and identifying real insects ($n = 5$), thought they would only be learning about insects ($n = 2$), thought the game would be about getting rid of insects ($n = 1$), or were hoping to actually touch insects with their hands ($n = 1$).

The wildlife biologist had a wider range of responses when asked about their experience in the game (Table 4.3). Some of the categories for wildlife biologist reflected the other two groups: educational ($n = 22$), fun/interesting ($n = 20$), and confusing/hard ($n = 5$). In addition they also made nondescript comments ($n = 2$) or simply recited what they did in the game ($n = 13$).

Table 4.3

Study Participants' Experience as a Wildlife Biologist

Category	Student Comments
Educational	<ul style="list-style-type: none"> • I learned a lot about what a biologist does as a job. • I got to learn more about scats and tracks and study the red wolf. • I learned about trees!!
Fun/Interesting	<ul style="list-style-type: none"> • It was really fun!!!!!! I liked that it was like a real mission you had to solve! If schools could do something like this when they were teaching something like a big subject I would love to go to school. • We looked into scat and tracks with personally was fun for me. It was like a mystery books but with animal.
Reciting	<ul style="list-style-type: none"> • I got to go out and conduct an investigation to find out more about who is poisoning the red wolves. • A farmer thought that a red wolf had been eating his livestock. I investigated and learned that it was a coyote that he shot and domestic dogs that had been eating his livestock. • I investigated places where there were supposedly red wolf attacks.
Confusing/Hard	<ul style="list-style-type: none"> • It was okay. It was kind of confusing it was hard to understand where to go. • It was confusing • It was hard identifying the footprints and scat, but the game itself wasn't hard to figure out.
Nondescript	<ul style="list-style-type: none"> • Ehhh... • Yeah

When the study participants were asked if they would be interested in learning more about wildlife science there were 44 positive responses, 16 negative responses, and two nondescript answers. Of the study participants who found the game confusing, three said they did not want to learn more about wildlife science, but one did. The student who said the track identification was hard, but the game itself was not, wanted to learn more about track and scat identification along with wildlife biology. Several study participants who said they had no interest in learning more about wildlife science stated that they had an interest in other areas of science.

- “I’m not very interested in wildlife science. The branch of science that appeals to me is more of flight and physics.”
- “No, DNA appeals more to me.”
- “I don’t think that wildlife science is the branch that I would want to be committed to, but I do want to be a marine biologist and help save coral reefs.”

Finally, when study participants were asked if the wildlife biologist role was different from what they expected (Table 4.4), 17 study participants thought that it was no different from what they expected and two study participants did not provide descriptive answers. Several other themes emerged in the remaining responses. Eleven study participants felt that there would be either more directly interacting with wildlife or at least viewing wildlife in the experience. Fourteen study participants thought the storyline was going to take a different direction. Several specifically thought there would be a larger medical component or lab experience for the wildlife biologist. Six study participants thought they would be either spending more time on the computer and did not realize they would be doing field tests or

thought they would be spending less time on the computer. Six study participants focused on the tracks and scat identification activity. Four study participants said there was more studying or learning in the activity than they expected. Two study participants said they went into the activity thinking it would be boring, but actually had a good time.

Several of the study participants made comments that showed they did not have a true understanding of wildlife biology or they had a misunderstanding of the profession:

- “It studied more tracks and scat than the animal itself.”
- “I expected to be looking around for animals, not looking for their tracks.”
- “I thought that as a wildlife biologist you would study animals and how they act in the wild. I didn’t consider that the scats and tracks of animals was a huge part of this subject.”
- “I thought biologist sat in a lab all day. I didn’t know biologist went out and collected stuff.”
- “I thought they studied live animals, but they study really everything about the animals, live or dead.”
- “I expected it would be more like a veterinarian.”
- “I thought we would study animals as a wildlife biologist but we helped people find things about animals.”

Many of the study participants thought there would be more interaction with the animals themselves either through direct physical contact or seeing the animals. These study participants seemed to think that wildlife biologist only study the physical animal, whereas a lot of the data they collect are from wildlife signs or observations from a distance. A couple

of study participants had the more stereotypical scientist in mind, thinking that wildlife biologists stayed in a lab.

Table 4.4

Study Participants' Expectations of the Wildlife Biologist Role

Category	Student Comment
No difference	<ul style="list-style-type: none"> • It wasn't • Exactly what I expected • It really wasn't...
More interaction with wildlife	<ul style="list-style-type: none"> • I thought you would do more touchy work. • I didn't actually see any wild animals. • I expected to do more with animals.
Either more or less time on the computer	<ul style="list-style-type: none"> • I thought it would be less on a computer. • I went out and conducted an investigation. I thought I would be sitting at desk learning about red wolves. • Yes. I thought we were going to not go outside to explore.
Focused on tracks and scat	<ul style="list-style-type: none"> • You got to look at track and scat. • I did not expect to be tracking.
Boring to fun	<ul style="list-style-type: none"> • I just thought that it was going to be boring but it really was fun. • I thought that it would be boring and just look at animals and study their habitats and instead it was pretty cool and interesting to see all the different types of animal prints.

Table 4.4 cont.

Category	Student Comment
Study	<ul style="list-style-type: none"> • There was a lot more to study and learn about than I initially thought. • The wild life biologist role was different from what I expected because I never knew that I would learn so much factual information!
Expected a Different Storyline	<ul style="list-style-type: none"> • I thought I was gonna deal with all animals but I guess thats why its called the Red Wolf Caper. • I thought you would have to make all sorts of antidotes and test them on the red wolves and see which antidote worked. • I expected it would be more like a veterinarian.

Interviews and Design Session Comments. Of the study participants that were interviewed, 15 were wildlife biologist, four were entomologist, and four were botanist. The reasons the study participants mentioned in the interviews for picking their roles matched up with the comments they wrote on the pretest in both the entomologist and wildlife biologist. Of the botanists that were interviewed, two mentioned their interest in plants, identifying plants and the role plants play in the ecosystem. The other two botanists mentioned the role was unique or unusual and something they did not know about. The entomologists once again mentioned either a previous positive experience ($n = 1$), an interest in insects ($n = 2$), or they wanted to learn more about insects ($n = 1$). The wildlife biologists that were interviewed mentioned either an affinity for animals ($n = 9$), an interest in the learning more about the

role of a biologist ($n = 4$), that the other roles did not sound interesting ($n = 1$), and misunderstood ($n = 1$). The student that misunderstood commented, “Because I like learning about plants and help creating medicine.” When the study participant was asked by the interviewer if they meant they played the botanist role, the student reconfirmed that they played the wildlife biologist.

During the design session the roles only came up once. In both the design session and when interviewed, study participants were asked about the next step in the game. The topic of new roles was brought up. Some of the study participants wanted roles that fit their interests like a law enforcement officer, a veterinarian, a builder, or a hunter. One student also mentioned being able to play the game as the wolf.

Question 3: How would students improve the Red Wolf Caper mSEG?

SEGR. The SEGR was used to evaluate the game in 14 different categories. The study participants’ total scores ranged from 4 to 28 with 28 being the highest possible score. The experts’ total scores ranged from 23 to 28. Based on the study participants’ scores (Table 4.5) all areas could use improvement, but specifically areas *included rules, increasing complexity, manipulation, identity, and tutorial/practice level*, which obtained an average score of 1.1 or lower. The experts’ scores showed that *increasing complexity, manipulation, tutorial/practice level, feedback, and pedagogical effectiveness* could all be improved. When the student scores were compared to the pilot test, 9 areas improved and 5 areas (i.e., *interactive, informed learning, manipulation, learning, and rules*) received a lower score.

Table 4.5

Student and Expert SEGR Scores

Category	Student Score		Expert Score	
	Mean	Standard Deviation	Mean	Standard Deviation
Prologue	1.59	0.49	2.00	0
Tutorial/ practice level	1.10	0.86	1.67	0.58
Interactive	1.62	0.56	2.00	0
Feedback	1.45	0.63	1.67	0.58
Identity	1.07	0.91	2.00	0
Immersion	1.31	0.68	2.00	0
Pleasurable Frustration	1.27	0.71	2.00	0
Manipulation	1.06	0.81	1.67	0.58
Increasing Complexity	1.00	0.82	1.33	1.15
Rules	0.80	0.77	2.00	0
Informed Learning	1.37	0.68	2.00	0
Learning	1.59	0.57	2.00	0
Pedagogical Effectiveness	1.41	0.54	1.67	0.58
Reading Efficiency	1.47	0.69	2.00	0
Total Score	18.13	5.15	- 26.00	2.65

In addition to the mean and standard deviation, a Kappa Score was generated for each category (Table 4.6). The level of agreement for all categories except *rules* was moderate (range = 0.41 – 0.60). *Rules* scored the lowest and had the lowest level of agreement, fair (range = 0.21 – 0.40).

Table 4.6

Kappa Scores by Category

Rated Category	Kappa Values	Level of Agreement
Prologue	0.4629	Moderate
Tutorial / Practice Level	0.4230	Moderate
Interactive	0.4686	Moderate
Feedback	0.5009	Moderate
Identity	0.4116	Moderate
Immersion	0.4601	Moderate
Pleasurable Frustration	0.4629	Moderate
Manipulation	0.4496	Moderate
Increasing Complexity	0.4297	Moderate
Rules	0.3878	Fair
Informed Learning	0.4600	Moderate
Learning	0.4905	Moderate
Pedagogical Effectiveness	0.5029	Moderate
Reading Efficiency	0.4658	Moderate
Overall Agreement	0.4555	Moderate

Design Sessions and Written Comments. Even with the fixes/improvements made to the game in the six days between the pilot and the main study, many of the comments in the design sessions reflected what the pilot group had said. Study participants still wanted better control of dialogue boxes and/or longer display time for the in-game text. This was the most common complaint among the study participants with 15 different comments on this one area. Another theme that carried over from the pilot test was the need for more

directions. Although not as common, there were several comments like “more directions/information,” or “It could have more information – a little introduction as to what to look for in the video.”

Most other comments aligned with the categories that were identified in SEGR as needing improvement: *rules, increasing complexity, manipulation, and identity* (Table 4.7). Although *tutorial/practice level* received a low score, there were no comments that directly related to this category.

Table 4.7

Student Comments Aligned to SEGR Categories

Category	Student Comments
Rules	<ul style="list-style-type: none"> • Open world – they don't like the boundaries • Map continues – open world
Increasing Complexity	<ul style="list-style-type: none"> • Make it harder at the end – increase complexity
Manipulation	<ul style="list-style-type: none"> • How do you grab an item? • Control of people movement- suggestion WASD for camera and arrows for moving • Stuck on plants • More controls – ex. Jump/ space bar • Stuck – jump to get out • Make controls easier • Glitch keeps minimizing. Mouse is too sensitive, Need to use a mouse not touch pad. Needs label the people. • Easier to move around
Identity	<ul style="list-style-type: none"> • Make 3rd person • Role of officer • Make it more like detective • Avatar (this comment was mentioned three times)

Even though some study participants wanted increasing complexity there were several study participants who made comments about the game being too hard:

- Hard to find people (coyote & hunter)
- Too many people in the concerned parent neighborhood
- Too complicated
- Automatically follow people
- More directions clearer goal
- Make things easier and more interactive

Study participants also wanted less reading and more voice-overs.

In the pilot test the *interaction* received a perfect score of two, but in the main study the study participants gave it a score of 1.63. Even though *interaction* received a fairly high score, study participants indicated that they still wanted more interaction:

- Allow them to do an autopsy on wolves (non-gross)
- Make more interactive
- More field tests
- Too much reading & not enough investigating on PDA
- More action & interaction
- Open crates
- Trigger events – chase culprit
- More interactive environment
- More track investigations (in field)

- Discover more as a wildlife biologist
- Chase sequence – bad guy

The two areas that stood out in the *interaction* comments was that the study participants wanted more field tests and they wanted a chase sequence with the culprit. Even though it was recommended in other AR research (Dunleavy, et al., 2009; Squire & Jan, 2007) to leave the “who done it part” open-ended, the study participants did not like this aspect. There were 7 recorded comments specifically directed toward wanting to know who did it and this did not include the general dialogue the study participants had with the staff. Study participants at the end of the sessions repeatedly asked the staff members who the culprit was and were disappointed when they found out there was no right or wrong answer. Finally, there were comments made about general fixes that need to be made to the game including being able to walk through walls, falling through floors, and getting stuck on different objects.

Interviews. In the 23 interviews the study participants were asked about their experience with the game. Eighteen of the responses were positive saying they enjoyed the game and/or perceived they had learned something they did not know prior to playing Red Wolf Caper. Some example responses were:

- “Educational experience I learned a lot of stuff about the biology and wildlife and find tracks and scat of different kinds of animals. And it was kind of like adventure games and I really like adventure games.”
- “I think I learned a lot and it was really fun because we had to solve a mystery and the game.”

Two study participants liked elements of the game, but not the whole experience. One student mentioned that she thought “It was pretty fun, the computer part, but going around was pretty trying. It was boring.” There was one student who did not like the game:

“Well it was a bit difficult to get around such. I looked around and I had a really hard time figuring it out and the same time the game seemed a bit boring. I like multiple animals and it just seems prejudice when you base it off one species. The game needs to be longer and it should be allowed to be produced and sold in stores.”

The final two study participants described what they did in the game, but did not make any positive or negative comments about the game.

When the study participants were asked directly about the AR portion of the game, 20 of the responses were positive (Table 4.8) and three were negative. A couple of the study participants commented that the AR portion was their favorite part. Several ($n = 12$) study participants liked the real life experience it provided them. A few ($n = 4$) of the study participants commented about how it provided them with activity instead of just sitting in front of a computer. Some study participants ($n = 4$) mentioned they liked the experience of using the PDA or GPS. The remaining positive comments just said they liked it or learn a lot, but did not go into more detail ($n = 5$). Several of the comments overlapped many of the areas mentioned.

Table 4.8

Study participants' Comments on the Augmented Reality Portion of Red Wolf Caper

Classification	Student Comments
Favorite	<ul style="list-style-type: none"> • I thought that was one of the best parts. Get out there and learn and learn even more about the wildlife biologist. • That was one of my favorite parts. It was fun to try to figure out and guess what the animal's tracks were and stuff.
Real Life Experience	<ul style="list-style-type: none"> • I thought that was cool because it gave you an experience like in real life. • Very helpful and very exciting to go be like a biologist • I thought that was a good experience a hands-on experience rather than just sitting here. Cool to go out and be a botanist I guess or whatever we were studying.
Activity	<ul style="list-style-type: none"> • Really good. It helps you not just sit and play things. Get some activity and do something. • Nice experience. Get off the computer and actually have a real time experience looking at scat and tracks.
PDA/ GPS Experience	<ul style="list-style-type: none"> • I think that was kind of fun too. It kind of taught me how to use a GPS because I didn't know how to do that either. • Fun gave you more experience. Helped you learn. Liked the PDA to guide you through it.

The three negative responses dealt with it being boring, hard to navigate with the PDA, and too much walking. Two of the three study participants who did not like the AR portion later

mentioned that do not like to spend time outdoors. They were the ones who thought the activity was boring or that there was too much walking involved. The third student liked to spend time outdoors playing soccer or walking around in the woods.

When the study participants were asked what the next step they would like to see in Red Wolf Caper, their comments varied greatly. Several study participants ($n = 5$) did not have an opinion. A few made comments that related to the SEGR evaluation, wanting the game to be interactive ($n = 2$) or adding more of a sense of identity either through new roles or having an actual avatar ($n = 2$). The new roles that were suggested included being able to play the wolf, a veterinarian, builder (who constructs habitats for animals), and a hunter. In addition, to comments reflecting the SEGR themes, two of the other themes reemerged in the interviews. One student brought up the need for more direction in the game “I would like more direction of what to do. More direction because it was a little confusing about what to do. But I eventually figured out but it would make it easier.” The theme — learning who the actual culprit was and being able to capture them, received two comments. The remainder of the comments related to expanding the game either through adding new missions ($n = 2$), focusing on new animals ($n = 2$), or adding a new element to the storyline ($n = 3$).

Study participants were asked to tell us what their favorite and least favorite parts of the game were (Table 4.9). The overwhelmingly favorite part of the game for the study participants was either the field test itself or some element of the field test. The least favorite parts were much more diverse, with the most common one being reading the books and interacting with the dialogue boxes, which had been mentioned previously. A few study

participants mentioned problems with manipulation and lack of direction, which also had previously been mentioned.

Table 4.9

Study participants' Favorite and Least Favorite Parts of Red Wolf Caper

Favorite	Least Favorite
<ul style="list-style-type: none"> • (could not hear on the recording) • Field Test • Field Test & exploring the in-game environments • Learning about entomology 	<ul style="list-style-type: none"> • Did not have one • Waiting for the veterinarian • Delivering the blood sample • (could not understand on the recording)
<ul style="list-style-type: none"> • Interactive & graphics • Field Test • Helping the wolves • Field Test • Delivering the blood sample and learning the results 	<ul style="list-style-type: none"> • Interacting with dialogue boxes • Graphics • Field Tests • First quiz • Reading the books
<ul style="list-style-type: none"> • No favorite part • Field Test (like real life) • Exploring the in-game environments & talking to avatars 	<ul style="list-style-type: none"> • Difficulty getting around and figuring stuff out • Interacting with dialogue boxes • Did not have one
<ul style="list-style-type: none"> • Field Test (looking for the items) • Corner of death* 	<ul style="list-style-type: none"> • Reading the books • Reading the books & having trouble completing missions for people

Table 4.9 cont.

Favorite	Least Favorite
<ul style="list-style-type: none"> • Field Test (GPS, finding items, identifying tracks) 	<ul style="list-style-type: none"> • Did not have one
<ul style="list-style-type: none"> • Investigating the house 	<ul style="list-style-type: none"> • Studying
<ul style="list-style-type: none"> • Field Test (identifying trees) 	<ul style="list-style-type: none"> • Walking
<ul style="list-style-type: none"> • Field Test 	<ul style="list-style-type: none"> • Trying to find people and items in-game
<ul style="list-style-type: none"> • Combination of computer and GPS 	<ul style="list-style-type: none"> • Confusing controls
<ul style="list-style-type: none"> • Liked the whole game 	<ul style="list-style-type: none"> • Mouse sensitivity
<ul style="list-style-type: none"> • Field Test 	<ul style="list-style-type: none"> • Lack of direction at beginning
<ul style="list-style-type: none"> • Field Test (identifying plants and use field guide) 	<ul style="list-style-type: none"> • Training center & virtual game – too confusing
<ul style="list-style-type: none"> • Field Test 	<ul style="list-style-type: none"> • Did not have one

* Corner of death is a nickname the researcher gave a location in the Hog Farm map. Study participants frequently got stuck in a corner by the barn and had to be shown how to get out.

This chapter contained the results for the three research questions; (a) Do mSEGs affect students' understanding of environmental concepts? (b) Which role do the students choose and what is their reasoning behind choosing that particular role? (c) How would students improve the Red Wolf Caper mSEG? The next chapter will discuss those results and their implications.

CHAPTER 5

Discussion

Overview

The results from the investigation of mSEGs in environmental education were reported in the previous chapter. This chapter will take a closer look at those results and try to explain some of the findings. In addition, implications of those results and future research will be presented in this chapter.

Question 1: Do mSEGs affect students' understanding of environmental education concepts?

Using the *Excellence in Environmental Education Guidelines for Learning (Pre K – 12)* (Simmons, 2004) framework, it was clear that the study participants were able to collect and develop explanations for the data they found in the game. They were able to collect data from the video, websites, interviews with the NPCs, and their own field investigations. They noted pieces of evidence from several of these sources on their student observation sheets and in their letters to the judge. However, they were not able to evaluate the evidence as well as hoped. They often listed circumstantial evidence in defense of their hypothesis. One of the commonly cited evidence was the hog farmer had chemicals and animal traps. They did not know if the chemicals were the same type that was being used to poison the red wolves, but many assumed they were. The animal traps were for small mammals used to trap rodents because the farmer told the study participants he had a rodent problem. If they investigated further they would have found evidence of the rodent problem around the grain bins. Some study participants did put more thought into their evaluation of the evidence. Many listed that

the hog farmer had killed a coyote thinking it was a red wolf and that he had motive for wanting to kill wolves because he believed the wolves had attacked his hogs. Yet the study participants who talked to the trapper should have learned that he had trapped and killed a red wolf by mistake. No study participants made mention of this in either the pilot study or the main study. This piece of evidence may have been lost in the storyline especially after the field test at the trapper location was cut from the wildlife biologist role. However, it was still brought to the attention of the botanist and entomologist in the course of the evidence summary for that area. The game needs to provide better scaffolding for the levels of evidence to improve this area. The addition of being able to take samples back to the lab for analysis would hopefully clear up this acceptance of circumstantial evidence.

An improved method of evaluating the evidence also should be created. There was some confusion among raters as to the classification used for the evidence. A couple of rubrics will be developed by the research staff using the guidelines from the *Excellence in Environmental Education Guidelines for Learning Pre K -12* (Simmons, 2004), one to measure the hypothesis and evidence and one for the letter to the judge.

The letters to the judge showed that study participants were able to apply concepts to real world situations. The food chain was only briefly mentioned in the video and showed the wolves killing rabbits. Yet the study participants were able to apply the concept of the predator role and how wolves keep prey populations in check and apply that concept to other prey species. Although the food chain and the role predators play in the ecosystem should have already been covered in school, study participants were still able to apply it to this particular situation showing that they understood the concepts. Both the food chain and the

role of predators in the ecosystem were pieces of information only briefly mentioned in the game, but the study participants felt it was important enough evidence to support the red wolf reintroduction project to a judge showing that they put appropriate value on the evidence in this case. This also showed that they understood some of the biological implications for the reintroduction of a species.

The social implications were not completely realized by the study participants. Some study participants picked up the idea “that false reports get made all the time” or “how a lot of people accuse [red wolves] for many things that really coyotes and foxes did.” In other words, people make assumptions about wildlife instead of basing their accusation on evidence. Other study participants took evidence against one individual and applied to a group, “I think that the farmers are poisoning the red wolves because the red wolves are eating their pets and food.” Understanding the role that an organism plays in society might be better achieved by adding some characters in the game that receive benefits from the red wolves instead of only having negative interactions. This could be done by adding someone in the ecotourism industry, showing a business benefit, or another farmer that appreciates having the wolves around because they regulate populations of crop pests.

A t-test showed there was a significant difference between pretest and posttest final scores for the participants, indicating the participants learned some basic content knowledge for the role they selected during the game. In the future it will be important to obtain a broader population sample to see if this applies to a variety of different types of students. Even though the posttest scores improved, there was still room for further improvement among the different roles. As the game is improved it will be interesting to see how this

affects the participants' scores. It also will be important to see if the participants retained the information they learned over a period of time and if they can apply the identification skills to different situations or other areas. All field guides are pretty similar. If a student played a wildlife biologist and used a track and scat field guide in Red Wolf Caper, would they be able to use a tree field guide in a different program? These are questions to examine in future phases of this project.

The study participants felt they learned a lot from the real world experiences of the field tests. Many of them mentioned how they learned about insect, tree, track, and scat identification during the game. A few study participants made reference to learning more about the role they played. Providing study participants with real world experiences that, at the same time, show them a glimpse of what scientist actually do on a daily basis may help encourage more study participants to explore the sciences. Two study participants thought that wildlife biologist stayed in a lab all day. It is misconceptions like these that mSEGs can help eliminate.

Question 2: Which role do the students choose and what is their reasoning behind choosing that particular role?

In addition to the improvements to the game described above, additional roles should be considered. The study participants suggested a variety of different roles including a veterinarian, an officer, a builder, a hunter, and a wolf. Many of these roles do not fit the current storyline nor do they provide for field test opportunities without redesigning the game. A wildlife officer and a wildlife veterinarian could probably be added to an AR version of the game because the study participants will be working in groups (see next

section for more details). Additional roles should be created, and with more time and discussion with study participants, viable alternatives may reveal themselves.

Because the *Unreal* game engine does not allow the study participants to have an avatar in-game, the role selection is the student's main sense of identity in the game. It is important for the study participants to find a role with which they can identify or in which they have an interest. A few of the study participants mentioned that the only reason they chose a wildlife biologist is because the other two roles sounded boring. Choosing the lesser evil should not be a reason the study participants use for picking a role. A couple of those study participants said they thought the experience was going to be boring, but ended up having fun. In some cases it may be beneficial to have a limited selection of roles to show study participants that a role is not always what they think. Similarly, it is important to show what these roles truly do and are not all the glorified parts of the job they may be expecting. Many of the study participants who chose the wildlife biologist role expected a lot of hands-on interaction with wildlife, which in most cases is a minor aspect of the job. The wildlife biologist role by far was the most popular, but the study participants who picked the botanist and entomologist roles seemed to have a stronger desire to learn something about those particular roles. One possible way to do this is to have videos of real scientist talking about what they do in their profession and some of the things they enjoy (or not enjoy) about their job.

The botanist role was originally designed so that the student would have to identify a variety of trees, vines, and herbaceous plants, but when looking for a field guide that was easy to use, there was not one that included all the plants that had been planned for that role.

A tree field guide was chosen because of its ease of use and instead of having more than one field guide for that role it was decided to have the botanist identify only trees. At that point, the programming of the game was almost complete. For future versions of the game it may be better to change that role to a forester instead of a botanist.

The mSEG allows participants to gain exposure in a number of roles in which, they might not normally be exposed. By gaining exposure to these roles it may open new doors that the participants had never considered before or it may tell them that a particular field they had been considering is not for them. MSEGs could potentially recruit students into the STEM fields by exposing them to potential jobs, offering them real world experiences in the field, and creating a foundation in some of the skills that job requires. As seen in this study, the mSEG corrected some student misconceptions about the roles. It also exposed participants to roles they previously thought were boring, which it turned out, they enjoyed. Even if the participants did not end up in that career field they still have a better knowledge of that topic area, which could possibly help them make better informed decisions in the future.

Augmented Reality and mSEGs. The augmented reality version will be designed to have study participants work in teams with each student playing a different role as suggested by past research (Dunleavy, et al., 2009; Klopfer, Perry, Squire, & Jan, 2005; Klopfer & Squire, 2008; Squire & Jan, 2007). Having study participants work in teams will give the study participants more experience with teamwork, communication, and collaboration, which are all a part of the 21st Century Skills initiative (Schrier, 2006). It was originally the plan of the designer that the study participants would work in teams, but there was no easy way to

accomplish this in Adventure Lab. Using a multiplayer platform in the mSEG instead of a single player would allow roles to work together and provide a different experience for the study participants. This will allow the study participants to get experience with some of the other roles as well as the one they are playing.

The connection between the three roles was lost in Red Wolf Caper. One of the chaperones had study participants share what they identified and how they identified it with the rest of the group if more than one role was present in the group. This provided the study participants a glimpse into the other roles. Except for the last day of the study, there was only one botanist or entomologist in the entire session. Because it was easier to take study participants out in larger groups than smaller groups to do the field tests, an attempt should be made to send mixed groups together out to do field tests in future single-player mSEGs. This will expose study participants to the other roles giving, them an idea of what the goals of other roles are and how each impact one another.

Question 3: How would students improve the Red Wolf Caper mSEG?

The results from the SEGR showed that, according to the study participants, all areas of Red Wolf Caper could be improved. Being the start of a design-based research project, this was to be expected. The experts' scores showed that only five areas of the game needed to be improved: *tutorial/practice level*, *feedback*, *manipulation*, *increasing complexity*, and *pedagogical effectiveness*. Although their scores only showed five areas of improvement, they were not the target audience, so the study participants' scores should be weighted more heavily. The goal is to make the game fun and educational for middle school students. It is

important to note that the experts, professionals in the education field, felt that the *pedagogical effectiveness* could be improved.

Most of the study participants' comments were reflected in the SEGR scores. One area that did not, however, was the *tutorial/practice level*. There were no specific comments made about this part of the game, yet the score for the category had the fifth lowest score. There were only two comments asking for information on what to look for in the opening video that was viewed between the practice level and the training center. This could have been because they did not see the role selection as part of the game or at least did not see it as the tutorial/practice level.

Increasing complexity was another category in which the study participants wanted improvement. Part of the problem with this category could be that the participants did not understand the rules in the game, which caused them to fail to see the content moving from easier to harder. *Rules* was the lowest ranked category and only received a fair level of agreement, which supports the idea that some of the study participants did not understand them.

The other categories that were in need of modification were *manipulation* and *identity*. *Manipulation* and *identity* were more about the platform, Adventure Lab, which was used to design the game, than the game itself. If the tutorial/practice island was improved it, may help participants better understand how to navigate through the game and therefore improve the *manipulation* score. The addition of an avatar was the main suggestion for improving *identity*, which currently is not possible in Adventure Lab. To replace the avatar, the game designers were trying to use the role identification as the identity for the

participants in this game. If the connection to the role identification was strengthened, the study participants may better understand their identity in the game.

Improvements to Red Wolf Caper. The results of the SEGR and the comments from the study participants indicated there are several changes that should be made to Red Wolf Caper. These changes include improving the in-game text management, clarity of directions, interaction, increasing complexity, tutorial/practice level, and manipulation. Other areas of the game could also be improved, but as specific areas are targeted for improvement, the game experience will change, and as it changes the scores for other categories may also change.

Several changes should be made to all modules of the mSEG Red Wolf Caper before it is tested again. As noted by the study participants, the in-game text needs to have a better system of control, so that study participants can control the textbox themselves instead of using a timer. This will better accommodate different reading speeds. The easiest way to change this is by putting the information in informative quiz boxes instead of dialogue boxes. Quiz boxes provide study participants with the option to close the box when they are done reading. As they close one box, another will pop-up automatically to continue the dialogue instead of having to have the study participants click on the object again, which may eliminate some of the confusion study participants were having.

Another recommendation some study participants had was about the clarity of directions. The directions should be reevaluated to see if they can better describe what the student is supposed to do without giving them step-by-step directions. Part of any video game, recreational or educational, is being able to explore the environment to find things and

trigger events to happen. With today's Internet, if someone becomes frustrated because they can not figure something out on their own, there are a number of sites for them look up locations of NPCs or objects, or to get step-by-step instructions on how to complete their mission or quest. If the goal is to encourage study participants to explore the natural environment, the mSEG can start with encouraging them to explore the artificial environment before sending them out to explore the real world.

Even though *interaction* scored high on the SEGR evaluation, study participants commented that they wanted more. The *increasing complexity* also could be improved, but as mentioned before, this could be partially due to the participants' lack of understanding of the rules in the game. *Interaction* and *increasing complexity* work together in a way and will be discussed collectively. The way the SEGR was designed, if one level in the game did not meet the basic requirements then subsequent levels would be impacted. Therefore, if the tutorial/practice level was improved, which is discussed in more detail below, then the *interaction* and *increasing complexity* scores also may be increased.

One possible way to improve *interaction* in addition to improving the tutorial/practice level is to reevaluate the whole antidote scenario of the game. Originally, the antidote was going to play a larger role in the game, but was pushed aside unintentionally in the version that was tested because of time, both in creating the game and in the time that study participants had to play the game. Originally, the goal was to make the game last about two hours, so informal education centers could use it as a program, but now this time limit seems unreasonable to obtain. Some of the study participants felt the length was just right whereas others felt the game was too short. Many study participants expressed the desire for more

field tests, which take up the largest amount of time in the game. The antidote can play a larger role in the game as part of the field tests. The original game had three field tests instead of two and not every NPC that the study participants interviewed had a field test. So, it is possible to create more field tests and add to the level of interaction. Field tests also could become more difficult as the study participants progress through the game adding to the complexity. The game was designed to provide the study participants with some freedom of choice of where they go instead of making the experience linear. To provide them with more freedom of choice, areas could be duplicated. To be congruent with a real investigation, the study participants could go back to an area more than once and receive new information upon each visit. As they visit an area more times the complexity will increase.

Another way that more interaction could be added, as well as answer the study participants' request for an actual culprit, is to choose a culprit and add a chase sequence in the game. As the study participants meet and talk with the different characters in the game or complete a field test, the culprit may have a consequence for the student actions. This also will add to the length of the game and the complexity. Other AR researchers recommended leaving games open-ended (Dunleavy, et al., 2009; Klopfer, Perry, Squire, Jan, et al., 2005; Squire & Jan, 2007), but the study participants clearly did not like this. It may be possible to keep the game open-ended and yet provide the students with the closure they want. After the students determine who the culprit is, they can report it to an NPC in the game. Once they make their selection it opens a new level. The new level will be the chase sequence with the character they chose as the culprit. Another option would be to redesign the game. Instead of having a specific culprit, there could be a couple of different choices and depending on the

evidence the study participants collect it leads them toward one culprit or another. By adding more consequences for the study participants' actions, the category of *rules* also may be improved.

The hog farmer was named as the number one suspect in the game, which was not the intention of the designer. All suspects were supposed to have an equally strong case against them. In identifying an actual culprit, it may be interesting to choose one of the characters that had a weaker storyline in the first version and improve it by providing strong evidence against that individual, then see if the study participants are misdirected by the circumstantial evidence around the hog farmer versus the stronger evidence of the new culprit. This will help to see how good the study participants are at synthesizing the evidence they are finding in the game.

Tutorial/practice level was another category that the study participants felt could be improved. It was the intention of the game designer for the character selection island to act as a practice level. The study participants could interact with the environment and interview the NPCs, which were two of the main skills required of the game. Perhaps by simply explaining in the directions that the island serves both as a chance to select a role and to become familiar with the basic movements, this would solve the problem. Another option to improve this area is by creating a tutorial explaining how to move through the game and take them step-by-step through some sample interactions before setting them free to explore the island and talk to the three NPCs. This may improve their manipulation through the environment and may reduce some of the confusion and/or problems study participants were having.

The final area of improvement was the *manipulation* component as defined by the SEGR. The main complaint with manipulation was how the controls worked for the game. Study participants used the touchpad for controlling the camera and the arrow keys or W, A, S, and D keys to move through the virtual world. These are the standard control keys for the *Unreal* game engine in which Adventure Lab was created and cannot be changed by the game designer. It is possible to change some of the settings in the game to make it easier for study participants to move around.

There was a lot of grass added in the game to help create a more natural looking environment. When an object is added to the game, collision for that object is automatically turned on. For things like grass the collision could be turned off making it easier for study participants to move. The “corner of death”, that one of the study participants mentioned as their favorite part, was caused by grass near the side of the hog farmer’s barn that blocked many players from moving. Even though there appeared to be plenty of room between the grass and the barn, the grass object is actually larger than what is visible. As the study participants walked into that corner they walked over the grass, but when they tried to back out, the grass was taller than they could walk over. The only way to get out was by turning the camera angle in a specific direction and continuously jumping forward until they were no longer near the grass. If collision for the grass was turned off, study participants would no longer get trapped in that corner. The study participants were using a touchpad on the laptop instead of a mouse. If a mouse was used that may improve some of the control for study participants.

Field Tests. The field tests were very successful and popular. Showing that the mSEG format has potential for encouraging study participants to explore and learn more about their surroundings. It also showed that this game has potential for an augmented reality version. The plans are to adapt the game into AR using a program called ARIS, which was created by Kurt Squire and his design team at the University of Wisconsin-Madison. Kurt Squire is currently one of the leading researchers in the field of AR games in the United States. *ARIS* runs on the iPhone® operating system, which allows it to run on iPhone®, iPod Touch®, and iPad®. This allows more flexibility in what can be done. Instead of having the study participants carry field guides with them, they can use field guide applications as an alternative. The software also offers more options than MITAR including the ability to collect some citizen science data, which could add to the exploration by the study participants. The plan is to use iPod Touch® with GPS cradles to eliminate the need for a cellular service plan that the iPad® and iPhone® require. Being able to play the game on an iPad® will also offer more accessibility to a larger audience. In past personal experiences at GPS workshops, some people had trouble with the small controls of handheld GPS units. The iPod Touch® is similar in size to those GPS units, but by using the larger touch screen of the iPad®, it may help people who have lost fine motor control in their hands or have vision impairments be able to play more easily. In addition, middle school students are more familiar with electronics, like iPod Touch® and iPad® compared to PDAs, which also may make it more accessible to a larger audience.

The game testing and design session were held completely outdoors. Each day temperatures reached over 90°F. Dunleavy et al. (2009) said this could influence the study

participants' experience with AR games. Generally, the study participants stayed in the shade of the patio, but when they went on the field tests two of the locations were completely in the sun. At least one group tried to speed through the field test because they were hot. Another group of study participants complained about the walking and the heat the entire time. The temperatures may have turned some of the study participants off from the overall experience or at least the field tests. It is hard to tell if this was the limiting factor because a couple of the study participants who did not like the experience said in their interviews that they did not like to spend time outdoors. Even with the heat, most of the study participants enjoyed the field test and wanted more. At least one student, who mentioned in his interview that he did not like to spend time outdoors, liked the experience of the field test.

Time. The game was designed to fit into a normal informal education program time period. Most school field trips to informal education centers only last two to three hours, whereas general public programs in informal education normally last one to two hours. It is still early in the design-based research phases of this project to determine what role time plays in the participants' learning. Informal education often occurs in "snapshots" instead of over long periods of time. With this in mind, it still needs to be determined if mSEGs are an appropriate tool for a "snapshot" session or if they need a longer time period for the participants to receive the full benefits it has to offer. Red Wolf Caper clearly can not be played easily in a two to three hour period and, in this particular case, the students wanted the game to be longer. Another game with less complexity could possibly be designed for a shorter time period, but would the students get as much out of it? At this stage it is hard to

tell how much time is required. A lot will be determined by the components used in the mSEG and the topic(s) covered.

Accessibility. One of the things that appeared early in this study was the issue of accessibility. For this first round of testing, accessibility was not a main focus. Because of this, the staff had to adjust on the fly when the parent of a child (or the child) with a disability that affected the student's game play notified them. There were three examples of this. One student had limited mobility; he was in a wheelchair, but could walk to a small degree. His mother notified the researcher in advance and an easy-access alternative location was created just for him to replace the deer hunter location that was on a trail in the woods. Another student identified herself as dyslexic. To help her through the game, staff members took turns reading the long paragraphs of text to her. Finally, the third student identified himself as color-blind. This only became a problem when he was trying to identify the red wolf in the pretest and posttest. The researcher gave him a verbal description of the coat color of the four different animals. The game easily could be made accessible by creating easy-access alternative locations for the different field tests. Voice-overs could be added for the larger amounts of text and written and/or verbal descriptions could be added for the photos in the game.

There was a student with Autism and another with Auspergers. The student with Autism expressed that the game was confusing for him, but otherwise did not have any problems. The student with Auspergers never complained of any issues, but the staff did have issues when he captured a toad and would not release it. The focus at his table then turned away from the game and to the toad and getting him to return it to the woods. It may be

necessary to express to study participants, through the game, the importance of leaving things where they find it to prevent further incidents like this. It is something that will be considered for the next version of the game.

A few study participants mentioned that they had trouble reading or had lower reading levels. They also expressed a desire for more voice-overs and a slower speaker in the voice-overs so they could take notes. In future versions of the game more voice-overs will be added to reduce the sheer amount of text, but all text will not be replaced.

Creating an accessible education game is important especially in informal education when the audience is often unknown until the time of the program. But designing a game that is accessible for everyone is hard to accomplish. Small changes like those listed above can be made and should make it more accessible for a larger audience.

Activity Theory

Reflecting on the Red Wolf Caper Activity Systems (Fig. 2.2) it becomes clear in this study the two main elements that affected the subject's outcome were the tools and the community. The use of the PDAs, which was novel to many of the participants, helped create an interest in the field identification part of the game. The field tests turned out to be one of the most popular parts of the game partially due to the use of the tools (e.g. PDAs, natural objects, and field guides). The community of the participants also played a role in the participant outcomes. Many of the students knew a least one other person in the session: a friend, relative, or classmate. In some cases there was a competitive component between the students who knew each other. In other cases, friends that came together often played the same role, so they experienced the game together by sharing information as they moved

through the SEG and worked together during the AR portion. The community atmosphere appeared to be an important part of the participants' enjoyment and learning experience.

Rules, as previously mentioned, also played an important part in the participants' outcome. *Rules* was the lowest ranked category in the SEGR evaluation. Even though it did not seem to dramatically affect the participants' experience, it still played a role for some of the students. The Kappa Score showed there was low agreement in this category meaning that the scores were not consistent among the participants. If the rules of the game were more clearly defined how would it affect the overall activity system? This is something to be examined in more detail in future phases of this study.

The game design activity system (Fig. 2.3) showed how the different components affect the improvements of the game. In this particular case, no component was more important than another. The small group design sessions allowed the division of labor to be more evenly distributed among the students instead of only allowing a few out-spoken students make all the suggestions.

Implications

General Use of Red Wolf Caper. Red Wolf Caper was specifically designed for this project, but there have been several requests already from informal and formal education groups asking to use the game. Two of the organizations work directly with educating people about the red wolf reintroduction program in NC. Even though the game has a location specific design, it could be easily adapted for other locations. The Adventure Lab portion of the mSEG would not need to be adapted in any way. A teacher or educator would need to purchase the Adventure Lab software and then load the game files on to the computer. The

MITAR portion would require three minor adjustments. One, the teacher would have to load a new aerial photograph representing the location they want to play the game, which can easily be done through the software. Two, they would need to move the marks for the concerned parent, hog farmer, and deer hunter to the locations they want to use on the aerial photograph. Three, the teacher would have to take new photographs of the sites where the tracks, plants, or insects are located for the field tests and load them into MITAR. MITAR is very user friendly and has good directions in the user manual, so this should not take very long for a teacher or educator to do.

It has even been suggested that with a few minor changes the game could be adapted to represent other wolf species (e.g., gray wolves). This would require some text changes in the Adventure Lab portion and some minor storyline adjustments. Other than those few changes it could easily be done, opening the game to a new audience.

Environmental Education. This study showed that there are potential uses for mSEGs in environmental education. These games allow study participants to collect, evaluate, and synthesize data. They also introduce students to real work experiences and application of skills. Many of these ideas are the objectives of environmental education and 21st Century Skills. MSEGs are another tool that environmental educators could use to help connect participants to the natural environment.

MSEGs could be used in a couple of different ways in environmental education. First, they could be used as strictly a game that participants play to learn more about a specific topic. For example, imagine an mSEG similar to the one in this study that focuses on a local park. The participants could play the SEG portion on the Internet and then download the AR

portion to play at the park. After visiting the park and conducting several field tests at once, they could conclude the game online or in a visitor center. A similar idea would involve using an AR game instead. In many cases, especially with today's economy, the staff available at local, state, and federal parks is limited, even more so in the case of educational staff. Most people who visit a park never interact with a staff member let alone participate in an education program. If AR games or mSEGs were designed to educate people about the park they are visiting, both historical and ecologically, then the park's message could potentially reach a larger audience. Games could be designed using free software like *ARIS* or *MITAR*, thus removing some of the expense for the park to create it. This is just one potential example of how mSEGs and AR could be used in informal education.

The second way that mSEGs could be used is as a product created by the participants. SEGs are being created by teachers as an assessment tool for their students and by the students themselves as a form of assessment. The students demonstrate their knowledge of a subject by creating a game to teach others about a particular topic. This is being done in formal classrooms, but the same idea could be used in informal education environments. Technology-based summer camps or afterschool programs in environmental education in the past have had students create blogs or wikis on a particular topic. The students will take their own photos and make videos then post them to these sites. Instead of creating a blog the students could make an mSEG on the topic that their friends or future visitors to that natural area could play.

Teachers could participate in workshops where they create their own field trips for their class. With the help of educators at local environmental education centers, they could

create an mSEG based around the location they will be visiting with their students. The teachers know best what materials need to be covered on a field trip. They could use the mSEG in conjunction with a center program to enhance the learning experience for their students.

Formal Education. SEGS also have a potential value in formal classrooms. As one student stated:

“It was really fun!!!!!! I liked that it was like a real mission you had to solve! If schools could do something like this when they were teaching something like a big subject I would love to go to school.”

The study participants appreciated the experience the mSEG offered. Because mSEGs are naturally divided into modules they could be incorporated into the daily lessons. A module could be completed each day, taking part of a class period instead of devoting several class periods to a SEG. MSEGs also require an assessment at the end of each module allowing the teacher to assess what the students are learning. A game that matches the theme of the topic being studied in class could be spread over the topic, emphasizing key points each day. Some days the students could be inside playing the SEG portions, whereas on other days the students could be outside doing field investigations. Labs could be tied into the storyline to make them feel more like real world applications of skills. Just as in the informal education setting, mSEGs can be used as a tool created by teachers or outside sources to assess their students or as a product created by the students as a form of assessment.

Teacher Education. MSEGs could be used in pre-service education in a number of ways. They could be used as a training tool for the pre-service teachers. Games could be

created to simulate possible scenarios in the classroom or on a field trip. Imagine pre-service teachers planning a field trip to a local zoo and then participating in a mock field trip. The first few modules are a SEG component about some of the planning and decisions teachers have to make for a field trip from budgeting to recruiting chaperones. The module of the game is an AR component where the teachers go through a mock field trip. As they move around the zoo, different problems will occur, from a student going missing to another one getting stung by a bee. Through the game the pre-service teachers could work together to handle the different issues that arise. This would allow the teachers a chance to get exposure to both positive and negative issues that could occur on a field trip with their students at the actual field trip location, instead of part of a discussion in the classroom.

Pre-service teachers also could be taught how to use mSEGs as a tool in their classroom to help them meet the requirements of 21st Century Skills, environmental education objectives, and other mandated requirements. They could be taught how to create the games themselves, teach students how to make the games, or how to locate already created games.

Future Research

More research is needed on this new form of SEG, including potential benefits in both formal and informal environments. In addition, different types of mSEGs will need to be investigated to see which combination of activities works in each setting. Using a combination of SEG and hands-on lab activities may work better in some formal classrooms, whereas mSEGs with SEG and AR may work better in informal settings. In general, more

work needs to be done on how to get a sedentary society back outdoors for both educational and health reasons.

Another area in which mSEGs may be beneficial is in training scenarios. SEGs have already been used in a number of industries to train staff. MSEGs would allow the staff a chance to work through computer simulations and getting hands-on experience at the same time. Similarly, researchers have been trying to find a way to train Citizen Scientists for various projects so that everyone would be equally trained and provide the same quality of data. Researchers are often limited in their time and in their resources to train all participants. Many Citizen Science projects take place over large regions – national projects and international projects. MSEGs could be a fun way to train volunteers and provide them with hands-on experience and to ensure the quality of data being collected.

Conclusion

Modular Serious Educational Games offer a number of potential benefits to both informal and formal education environments. They include built-in assessments to allow teachers and educators a chance to see what students are learning from the experience. Dividing the game into modules allows it to be easily separated into sections so it can be played over days or all in one sitting. MSEGs can offer students a chance to explore different roles, use various skills, and apply their knowledge to real world applications.

MSEGs also offer a potential way to encourage students to explore their natural surroundings. Games like these can be played in schoolyards, in a park with friends, or with their family. The quality time students could spend with family or friends could potentially improve the learning experience and make the game more enjoyable.

Many of the students commented on how they appreciated not sitting in front of a computer the entire time playing a video game. They enjoyed the break the field tests offered them even when that meant trekking around on extremely hot days. If students were excited about the experiences the game offered them in less than ideal conditions, imagine how involved they may become in more ideal conditions or how much they may learn.

REFERENCES

- "Corporate Survey Looks at Benefits of Outdoor Time" (2008). Corporate Survey Looks at Benefits of Outdoor Time Retrieved March, 2009, from http://www.childrenandnature.org/news/detail/corporate_survey_looks_at_benefits_of_outdoor_time/
- Abe, M., Yoshimura, T., Koizumi, S., Hasegawa, N., Osaki, T., Yasukawa, N., et al. (2005). Virtual forest: design and evaluation of a walk-through system for forest education. *Journal of Forest Research*, 10(3), 189-197.
- Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: identification of appropriate game types and game elements. *British Journal of Educational Technology*, 30(4), 311-321.
- Annetta, L. A. (2008a). *Educational games and how librarians can play*. Paper presented at the Launch NC conference.
- Annetta, L. A. (2008b). Video Games in Education: Why They Should Be Used and How They Are Being Used. *Theory into Practice*, 47(3), 229 - 239.
- Annetta, L. A. (2010). *Serious educational games: A look into the rabbit hole*. Paper presented at the National Science Foundation.
- Annetta, L. A. (Ed.). (2008c). *Serious Educational Games*. Rotterdam: Sense Publishers.
- Annetta, L. A., Lamb, R., & Stone, M. (in press 2010). Assessing Serious Educational Games: The Development of a Scoring Rubric. In L. A. A. a. S. Bronack (Ed.), *Serious Educational Game Assessment: Practical Methods and Models for*

- Educational Games, Simulations and Virtual Worlds*. Amsterdam, The Netherlands: Sense Publishers.
- Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education*, *53*(1), 74-85.
- Balmford, A., Clegg, L., Coulson, T., & Taylor, J. (2002). Why Conservationists Should Heed Pokemon. *Science*, *295*(5564), 2367b-.
- Barab, S., & Squire, K. D. (2004). Introduction: Design-Based Research: Putting a Stake in the Ground. *The Journal of the Learning Sciences*, *13*(1), 1-14.
- Becker, M. L., Congalton, R. G., Budd, R., & Fried, A. (1998). A GLOBE Collaboration to Develop Land Cover Data Collection and Analysis Protocols. *Journal of Science Education and Technology*, *7*(1), 85-96.
- Belle, T. J. L. (1982). Formal, Nonformal and Informal Education: A Holistic Perspective on Lifelong Learning. *International Review of Education / Internationale Zeitschrift für Erziehungswissenschaft / Revue Internationale de l'Education*, *28*(2), 159-175.
- Benford, S. (2005). *Future Location-Based Experiences*.
- Benford, S., Anastasi, R., Flintham, M., Drozd, A., Crabtree, A., & Greenhalgh, C. (2003). Coping with uncertainty in a location-based game. *IEEE Pervasive Computing*, *2*(3), 34-41.
- Billinghurst, M. (2002). Augmented Reality in Education. *New Horizons for Learning*.

- Burdette, H. L., & Whitaker, R. C. (2005). Resurrecting Free Play in Young Children: Looking Beyond Fitness and Fatness to Attention, Affiliation, and Affect. *Arch Pediatr Adolesc Med*, 159(1), 46-50.
- Centers for Disease Control and Prevention [CDC] (2009). Childhood Overweight and Obesity Retrieved 2/22/2010, 2010, from www.cdc.gov/obesity/childhood/index.html
- Chavez, D. (2009). Youth Day in Los Angeles: Evaluating the Role of Technology in Children's Nature Activities. *Children, Youth and Environments*, 19(1), 102-124.
- Chen, F. C., Lai, C. H., Yang, J. C., Liang, J. S., & Chan, T.-W. (2008). *Evaluating the Effects of Mobile Technology on an Outdoor Experiential Learning*. Paper presented at the Wireless, Mobile, and Ubiquitous Technology in Education, 2008. WMUTE 2008. Fifth IEEE International Conference on.
- Clements, R. (2004). An Investigation of the Status of Outdoor Play. *Contemporary Issues in Early Childhood*, 5(1), 68-80.
- Cole, M., & Engerström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Solomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1-45).
- Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science*, 323(5910), 66-69.
- Dede, C., Nelson, B., Ketelhut, D. J., Clarke, J., & Bowman, C. (2004). *Design-based research strategies for studying situated learning in a multi-user virtual environment*. Paper presented at the Proceedings of the 6th international conference on Learning sciences.

- Duda, M. D., Bissell, S. J., & Young, K. C. (1998). *Wildlife and the American mind: public opinion on and attitudes toward fish and wildlife management*. Harrisonburg, Virginia: Responsive Management.
- Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. [Article]. *Journal of Science Education and Technology*, 18(1), 7-22.
- Duvall, J., & Zint, M. (2007). A Review of Research on the Effectiveness of Environmental Education in Promoting Intergenerational Learning. *The Journal of Environmental Education*, 38(4), 14-24.
- Eshach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology*, 16(2), 171-190.
- Faber Taylor, A., & Kuo, F. E. (2009). Children With Attention Deficits Concentrate Better After Walk in the Park. *J Atten Disord*, 12(5), 402-409.
- Fotouhi-Ghazvini, F. (2009). *Designing Augmented Reality Games for Mobile Learning Using an Instructional-Motivational Paradigm*.
- Hand, B., Hohenshell, L., & Prain, V. (2004). Exploring students' responses to conceptual questions when engaged with planned writing experiences: A study with year 10 science students. *Journal of Research in Science Teaching*, 41(2), 186-210.
- Heimlich, J. (2003). Environmental Educators on the Web: Results of a National Study of Users and Nonusers. *The Journal of Environmental Education*, 34(3), 4-11.

- Hohenshell, L. M., & Hand, B. (2006). Writing-to-learn Strategies in Secondary School Cell Biology: A mixed method study. *International Journal of Science Education*, 28(2), 261 - 289.
- Howland, D., & Becker, M. L. (2002). GLOBE—The Science Behind Launching an International Environmental Education Program. *Journal of Science Education and Technology*, 11(3), 199-210.
- Huh, S., & Gordon, C. (2008). Vitamin D deficiency in children and adolescents: Epidemiology, impact and treatment. *Reviews in Endocrine & Metabolic Disorders*, 9(2), 161-170.
- Huizenga, J., Admiraal, W., Akkerman, S., & ten Dam, G. (2009). Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game. [Article]. *Journal of Computer Assisted Learning*, 25(4), 332-344.
- Institute for Environmental Studies (2009, December 2-4, 2009). *2009 Amsterdam Conference on the Human Dimensions of Global Environmental Change*. Paper presented at the Earth System Governance: People, Places, and the Planet, Amsterdam.
- Ioannidou, I. A., Paraskevopoulos, S., & Tzionas, P. (2006). An interactive computer graphics interface for the introduction of fuzzy inference in environmental education. *Interacting with Computers*, 18(4), 683-708.
- Johnson, L., Levine, A., Smith, R, & Stone, S. (2010). *The 2010 Horizon Report*. Austin, Texas.

- Kareiva, P. (2008). Ominous trends in nature recreation. *Proceedings of the National Academy of Sciences*, 105(8), 2757-2758.
- Kellert, S. R. (2005). In Building for Life: Designing and Understanding the Human-Nature Connection *Nature and Childhood Development*. Washington, DC: Island Press.
- Ketelhut, D. (2007). The Impact of Student Self-efficacy on Scientific Inquiry Skills: An Exploratory Investigation in River City , a Multi-user Virtual Environment. *Journal of Science Education and Technology*, 16(1), 99-111.
- Kiefer, P., Matyas, S., & Schlieder, C. (2006). Learning About Cultural Heritage by Playing Geogames. In R. Harper, M. Rauterberg & M. Combetto (Eds.), *Entertainment Computing - ICEC 2006* (pp. 217-228). Berlin, Germany: Springer.
- Klopfer, E., Perry, J., Squire, K. D., & Jan, M.-F. (2005). *Collaborative learning through augmented reality role playing*. Paper presented at the Proceedings of th 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years! ,
- Klopfer, E., Perry, J., Squire, K. D., Jan, M. F., & Steinkuehler, C. (2005). *Mystery at the museum - A collaborative game for museum education*. Mahwah: Lawrence Erlbaum Assoc Publ.
- Klopfer, E., & Squire, K. D. (2008). Environmental Detectives - the development of an augmented reality platform for environmental simulations. *Educational Technology Research & Development*, 56(2), 203-228.
- Klopfer, E., & Yoon, S. (2004). Developing games and simulations for today and tomorrow's tech savvy youth. *TechTrends*, 49(3), 33-41.

- Kolvoord, B., Charles, M., & Purcell, S. (2010). *What Happens After the Professional Development: Case Studies on Implementing GIS in the Classroom*. Paper presented at the National Association for Research in Science Teaching Annual International Conference.
- Kulo, V., Bodzin, A., Anastasio, D., Peffer, T., Sahagian, D., & Cirucci, L. (2010). *Examining the Implementation of a Geospatial Information Technologies-supported Energy Unit in an Urban Middle School*. Paper presented at the 2010 National Association for Research in Science Teaching Annual International Conference.
- Kuo, F. E., & Faber Taylor, A. (2004). A Potential Natural Treatment for Attention-Deficit/Hyperactivity Disorder: Evidence From a National Study. *Am J Public Health, 94*(9), 1580-1586.
- Lim, C. P., & Hang, D. (2003). An activity theory approach to research of ICT integration in Singapore schools. *Computers & Education, 41*(1), 49-63.
- Louv, R. (2008). *Last Child in the Woods* (second ed.). Chapel Hill: Algonquin Books of Chapel Hill.
- Mayo, M. J. (2009). Video Games: A Route to Large-Scale STEM Education? *Science, 323*(5910), 79-82.
- Moeller, R. M., Cootey, J. L., & McAllister, K. S. (2007). "The Peripatos could not have looked like that," and other educational outcomes from student design. In B. E. Shelton & D. A. Wiley (Eds.), *The Design and Use of Simulation Computer Games in Education* (pp. 131-154). Rotterdam, The Netherlands: Sense Publishers.

- Murphy, A. P., & Coppola, R. K. (1997). *GLOBE: A Science/ Education Partnership Program*. Paper presented at the Annual Meeting of the American Educational Research Association.
- Mwanza, D. (2001). *Where theory meets practice: A case for an Activity Theory based methodology to guide computer system design*. Paper presented at the INTERACT' 2001: Eighth IFIP TC 12 International Conference on Human-Computer Interaction, Oxford, UK.
- National No Child Left Inside Coalition (2010). Nature Deficit Disorder Retrieved March 19, 2010, from <http://www.cbf.org/Page.aspx?pid=702>
- Nelson, B. (2007). Exploring the Use of Individualized, Reflective Guidance In an Educational Multi-User Virtual Environment. *Journal of Science Education and Technology, 16*(1), 83-97.
- Nicklas, D., Pfisterer, C., & Mitschang, B. (2001). Towards Location-based Games. In L. W. S. e. al. (Ed.), *Applications and Development of Computer Games in the 21st Century: ADCOG 21*. Hongking Special Administrative Region, China.
- North Carolina Office of Environmental Education (2009). *The North Carolina Environmental Education Plan*.
- Oblinger, D. G. (2004). The Next Generation of Educational Engagement. *Journal of Interactive Media in Education, 8*.
- Okada, M., Tarumi, H., Yoshimura, T., Moriya, K., & Sakai, T. (2002). Realization of Digital Environmental Education — A Future Style of Environmental Education in

- Dynamically Changing Virtual Environment — *Digital Cities II: Computational and Sociological Approaches* (pp. 371-379).
- Pergams, O. R. W., & Zaradic, P. A. (2006). Is love of nature in the US becoming love of electronic media? 16-year downtrend in national park visits explained by watching movies, playing video games, internet use, and oil prices. *Journal of Environmental Management*, 80(4), 387-393.
- Pergams, O. R. W., & Zaradic, P. A. (2008). Evidence for a fundamental and pervasive shift away from nature-based recreation. *Proceedings of the National Academy of Sciences*, 105(7), 2295-2300.
- Prain, V., & Hand, B. (1996). Writing for learning in the junior secondary science classroom: issues arising from a case study. *International Journal of Science Education*, 18(1), 117 - 128.
- Rashid, O., Mullins, I., Coulton, P., & Edwards, R. (2006). Extending cyberspace: location based games using cellular phones. *Comput. Entertain.*, 4(1), 4.
- Rose, K. A., Morgan, I. G., Ip, J., Kifley, A., Huynh, S., Smith, W., et al. (2008). Outdoor Activity Reduces the Prevalence of Myopia in Children. *Ophthalmology*, 115(8), 1279-1285.
- Schmalstieg, D., & Wagner, D. (2007). *Experience with Handheld Augmented Reality*. Paper presented at the The Sixth IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR'07).
- Schrier, K. (2006). *Using augmented reality games to teach 21st century skills*. Paper presented at the SIGGRAPH 2006.

- Schwabe, G., & Göth, C. (2005). Mobile learning with a mobile game: design and motivational effects. *Journal of Computer Assisted Learning, 21*, 204-216.
- Shelton, B. E. (2002). Augmented Reality and Education. *New Horizons for Learning, 9*(1).
- Simmons, D. (Ed.). (2004). *Excellence in environmental education: Guidelines for learning (K-12)*. Rock Springs, GA: North American Association for Environmental Education.
- Sobel, D. (1997). Sense of Place Education for the Elementary Years.
- Sobel, D. (1999). Beyond Ecophobia: Reclaiming the Heart in Nature Education. *Nature Study, 49*, 4-12.
- Spikol, D., & Milrad, M. (2008). *Combining Physical Activities and Mobile Games to Promote Novel Learning Practices*. Paper presented at the Proceedings of the Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education.
- Squire, K. D. (2005). Changing the Game: What Happens When Video Games Enter the Classroom? *Innovate: Journal of Online Education, 1*.
- Squire, K. D. (2006). From Content to Context: Videogames as Designed Experience. *Educational Researcher, 35*(8), 19-29.
- Squire, K. D., & Barab, S. (2004). *Replaying history: engaging urban underserved students in learning world history through computer simulation games*. Paper presented at the Proceedings of the 6th international conference on Learning sciences.

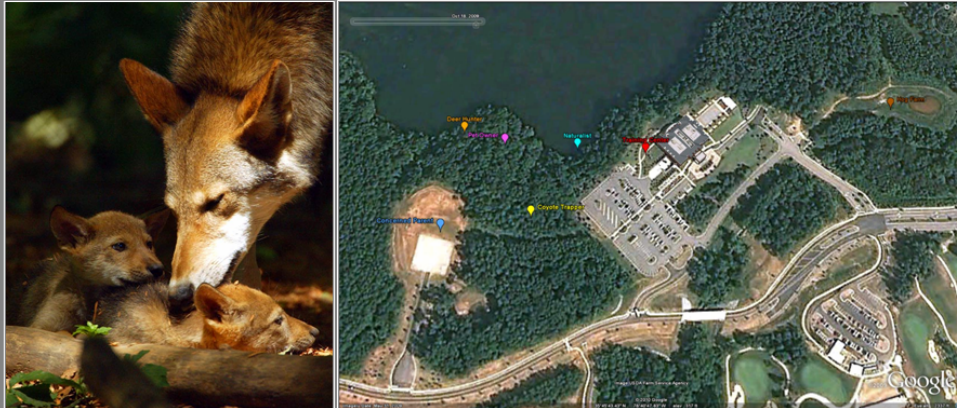
- Squire, K. D., & Jan, M. (2007). Mad City Mystery: Developing Scientific Argumentation Skills with a Place-based Augmented Reality Game on Handheld Computers. *Journal of Science Education and Technology*, 16(1), 5-29.
- Squire, K. D., Jan, M., Matthews, J., Wagler, M., Martin, J., Devane, B., et al. (2007). Wherever You Go, There you are : Place-Based Augmented Reality Games for Learning. In B. E. Shelton & D. Wiley (Eds.), *The Design and Use of Simulation Computer Games in Education*. Rotterdam, The Netherlands: Sense Publishers.
- Squire, K. D., & Jenkins, H. (2003). Harness the Power of Games in Education. *In Sight*, 3, 5 - 33.
- Thai, A. M., Lowenstein, D., Ching, D., & Rejeski, D. (2009). *Game Changer: Investing in digital play to advance children's learning and health*. New York: The Joan Ganz Cooney Center at Sesame Workshop.
- The Design-Based Research Collective (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, 32(1), 5-8.
- Tudor, M., & Dvornich, K. (2001). The NatureMapping Program: Resource Agency Environmental Education Reform. *The Journal of Environmental Education*, 32(2), 8-14.
- UNCED (1992). *Agenda 21: Programme of Action for Sustainable Development*.
- UNESCO-UNEP (1975). *The Belgrade Charter: a framework for environmental education*. Paper presented at the International Workshop on Environmental Education.

- UNESCO-UNEP (1977, October 14-26). *Intergovernmental Conference on Environmental Education Final Report*. Paper presented at the Intergovernmental Conference on Environmental Education, Tbilisi, USSR.
- UNESCO-UNEP (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. from <http://unfccc.int/resource/docs/convkp/kpeng.pdf>
- United Nations (2003). *Report of the World Summit on Sustainable Development*.
- Valentine, G., & McKendrick, J. (1997). Children's outdoor play: Exploring parental concerns about children's safety and the changing nature of childhood. *Geoforum*, 28(2), 219-235.
- Wang, F., & Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5-23.
- Wells, N. M., & Evans, G. W. (2003). Nearby Nature: A Buffer of Life Stress among Rural Children. *Environment and Behavior*, 35(3), 311-330.
- Yore, L. D., Hand, B., Goldman, S. R., Hildebrand, G. M., Osborne, J. F., Treagust, D. F., et al. (2004). New Directions in Language and Science Education Research. *Reading Research Quarterly*, 39(3), 347-352.

APPENDICES

NC STATE UNIVERSITY

Video Game Testers Wanted



Looking for middle school students to test a new video game about the NC red wolf reintroduction.

Details:

- Come and join us for a morning or afternoon of fun as you learn about the red wolf reintroduction in NC and play with cutting edge technology.
- The *Red Wolf Caper* is a new video game made of two components; a traditional computer game and an augmented reality game. Augmented reality (AR) games are played on PDAs with GPS units. AR allows virtual information to be overlaid on the real world settings allowing the game to be played indoors and outdoors.
- Participants will play the game and act as assistant designers to improve the game for future players.
- Email Beth Folta to schedule to participate on one of 6 different times / dates:

Morning Sessions (9-12pm)	Afternoon Sessions (1-4 pm)
June 14, 21,22, 23	June 21, 22, 23
- Location: Dorothy and Roy Park Alumni Center on Centennial Campus
- Parental permission is required to participate.

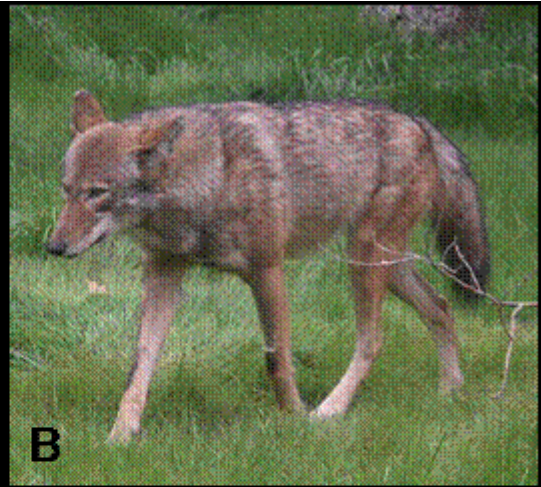
For more information, please contact Beth Folta at 919-269-2767/
wildlife.educator@gmail.com

Appendix B

Wildlife Biologist Pretest/ Posttest

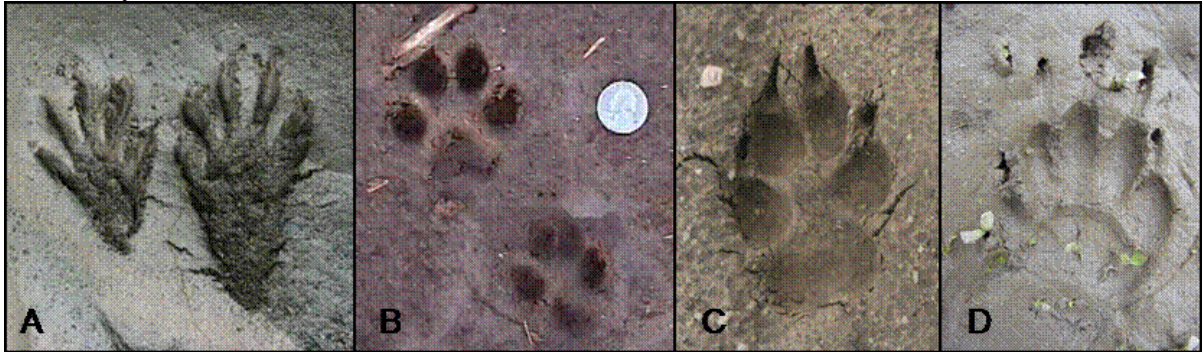
1. Define necropsy
 - a. another term for a human autopsy
 - b. physical examination of a live animal
 - c. looking at a tissue sample under a microscope
 - d. an animal autopsy

2. Identify the red wolf



3. How is hybridization a problem with the red wolf population?
- a. Red wolves in eastern NC are pairing up with coyotes instead of other wolves creating genetic hybrid offspring.
 - b. Hybridization is not a problem with the current red wolf population.
 - c. Hybridization is one of the problems that originally put the red wolves in danger and why the recovery program was started.
 - d. A & C
 - e. B & C

4. Identify the cat track.



5. What are some of the common concerns with the reintroduction of the red wolves?
- a. that pets, livestock & children are in danger from being attacked
 - b. that the red wolves have become too domesticated after living in zoos
 - c. the populations of other animals like deer won't be reduced because of the new predators
 - d. that they will require extensive vet care

Entomologist Pretest/ Posttest

1. Which of these invertebrates is actually a crustacean?
 - a. termites
 - b. ticks
 - c. pillbugs
 - d. chiggers

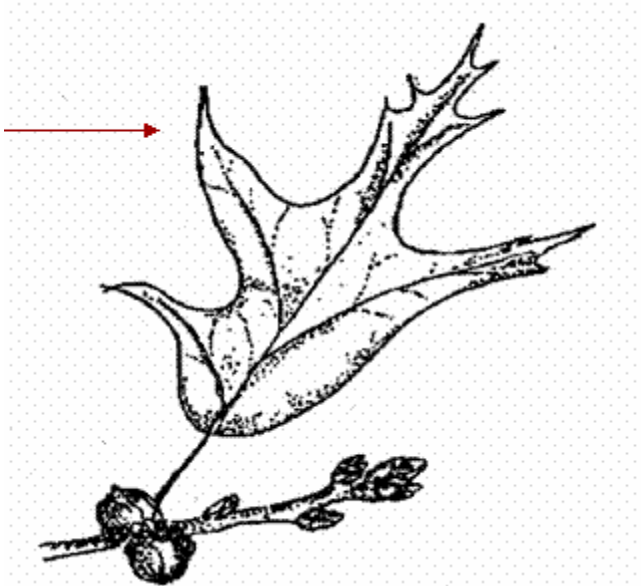
2. What are the identifying characteristics of an insect?
 - a. 1 head, 1 thorax, and 4 legs
 - b. 3 body parts, 6 legs, and no antennae
 - c. 2 body parts, 8 legs, and 8 eyes
 - d. 3 body parts, 6 legs, and 2 antennae

3. Termites are one example of an insect that uses what to communicate?
 - a. sound
 - b. light flashes
 - c. pheromones
 - d. physical movement

4. How do pillbugs breathe?
 - a. gills
 - b. spiracles
 - c. skin
 - d. lungs

5. What are some of the common concerns with the reintroduction of the red wolves?
 - a. that pets, livestock & children are in danger from being attacked
 - b. that the red wolves have become too domesticated after living in zoos
 - c. the populations of other animals like deer won't be reduced because of the new predators
 - d. that they will require extensive vet care

Botanist Pretest/ Posttest



1. Name the part of the leaf
- a. sinus
 - b. lobe
 - c. stipule
 - d. petiole

2. Identify the sweetgum leaf.



3. A historical use of white oak acorns was:
- a. nuts for cookies, pies, and cakes
 - b. marbles
 - c. ground to make flour
 - d. tea for sore throats
 - e. C & D
 - f. all of the above

4. Define invasive species.
 - a. A plant that is in the way.
 - b. It is a non-native species that has been introduced to an area and has the tendency to take over/ change the ecosystem due to the lack of natural predators.
 - c. A native species that can take over the area.
 - d. A non-native species that co-habitats in an ecosystem with no significant effects to the ecosystem.

5. What are some of the common concerns with the reintroduction of the red wolves?
 - a. that pets, livestock & children are in danger from being attacked
 - b. that the red wolves have become too domesticated after living in zoos
 - c. the populations of other animals like deer won't be reduced because of the new predators
 - d. that they will require extensive vet care

Weekly Activities

	Do not participate	Hours per week					Notes
		0-2	2-4	4-6	6-8	> 8	
Organized sports (please specify sports)							
Performing arts (dance, drama, singing)							
Scouts (Girl or Boy Scouts)							
Watching TV							
Visual Arts (drawing, painting, sculpture, etc.)							
Video and computer games (PS3, Wii, Xbox, etc)							
Computer (surfing the Internet, chat sessions, social networking sites, blogging)							
Mobile games (Nintendo DS, PSP, iPod touch, smartphones)							
Free play – Indoors							
Free play – Outdoors							
Reading (books, comics, magazines, etc.)							
School Clubs (please specify which clubs)							
Biking, rollerblading, skateboarding, scooter, go for a walk, etc.							

Monthly Activities

	Do not participate	# of Times per Month				
		0-2	2-4	4-6	6-8	> 8
Hiking						
Camping						
Visit a park						
Visit an arcade						
Go to the movies						
Rent a movie						
Visit the mall						
Fishing or hunting						
Boating						
Visit a museum						

If you play any video, computer, or mobile games please answer the next question.

Types of games	Check the game types you play	Rank your top 3 game types
Action - God of War, Call of Duty, etc.		
Adventure - Lego Star Wars, Ratchet & Clank, etc.		
Arcade - Pac Man, Space Invaders, etc.		
Casual games - Bejeweled, solitaire, board games, etc.		
Online Gaming - Aion, World of Warcraft, Star Wars Galaxies, etc.		
Racing - Mario Kart, Burnout, Gran Turismo, etc.		
Rhythm - Guitar Hero, Rock Band, Dance Dance Revolution, etc.		
Role-Playing - Final Fantasy, Zelda, Dragon Age, etc.		
Simulations - The Sims, Spore, etc.		
Social applications - Mafia Wars, Farmville, etc.		
Sports Games - Madden NFL, NBA Live, Deer Hunter, etc.		
Strategy - Age of Empires, Civilization, etc		

Appendix D

Serious Educational Game Rubric [SEGR]

Category	0	1	2	Score
Prologue	No introduction provided	An introduction is provided but doesn't communicate the game's goal's	An introduction is provided with clear communication to the game's goals	
Tutorial/practice level	No tutorial or practice level included	A tutorial or practice level is included but contextual feedback is missing for the player	A tutorial or practice level is included and clear feedback is given to the player so they have the skills to be successful in the game	
Interactive	There is no interaction with NPCs or world objects	There is little interaction with NPCs or world objects or the interaction does not provide relevant information for the player to be successful	There is much interaction with NPCs and/or world objects and the interaction provides relevant information for the player to succeed and the interface is transparent and intuitive	
Feedback	There is no content or level context feedback provided to the player	There is feedback provided to the player but it is not immediate and the content or level context is missing or incorrect	Feedback is immediate, with correct content, and contextually relevant	
Identity	The player does not have a choice of avatar	The player has avatar choices but does not report a connection to the avatar choice	The player has an avatar choice and verbalizes why that avatar was chosen and reports a sense of connection to the avatar	
Immersion	Player lacks engagement with the game	Player is relatively engaged in the game but reports not gaining a sense of presence or identity during game play	Player is so engaged that he/she reaches <i>Flow</i>	
Pleasurable frustration	Game challenges do not match player skill level	Game does not adjust challenges and provide feedback, which makes players feel challenged while the success is also attainable.	Player reaches <i>Flow</i> and the game challenges and provides enough feedback for the player to feel the goal is attainable	
Manipulation	Players cannot manipulate in world objects	Players can manipulate in world objects but the manipulation has no consequence	Players can manipulate in world objects and the manipulation has consequences	
Increasing complexity	There is no progressive skills needed to attain game's goal	The game increases in complexity but the climax event does not account for all skills acquired	The game increases in complexity and the climax event accounts for all skills acquired	
Rules	There are no rules to the game	There are rules without consequences	There are explicit rules and there are clear consequences for breaking the rules	

Informed Learning	There is no sign of data collection	User data is collected in one or two ways	Data is collected in multiple ways and an after action review is provided for the player	
Learning	The model underlying the game is not valid to the content and skills taught	The model underlying the game is valid to the content and skills taught but not simplified sufficiently so that the game is less complicated than teaching the same material in the real world	The model underlying the game is valid to the content and skills taught, yet simplified sufficiently that the game is less complicated than teaching the same material in the real world	
Pedagogical (teaching) Effectiveness	There was no understandable learning content in the game	The game material could be taught just as effectively, or largely as effectively, without the complexities and cost of using an immersive interface	The game material could not be taught without the complexities and cost of using an immersive interface	
Reading Efficiency	In game text was not on an appropriate reading level for the target audience	In game text was on a developmentally appropriate reading level for the target audience but was not pedagogically scaffolded with audio	In game text was on a developmentally appropriate reading level for the target audience and was pedagogically scaffolded with audio	

Appendix E

Hypothesis (Who is poisoning the red wolves and why?)

List your supporting evidence:

-
-
-
-

Write a brief letter to the local judge explaining the importance of the red wolf reintroduction project.

Appendix F

Role Selection Survey

Will be added to knowledge pre-test.

1. Why did you choose to be a [botanist, wildlife biologist, entomologist]?*

Will be added to knowledge post-test.

1. Explain your experience as a(n) [botanist, wildlife biologist, entomologist] in the game.*
2. Are you interested in learning more about [botany, wildlife science, entomology]?*
Please explain what about that particular branch of science appeals to you.
3. How was the [botanist, wildlife biologist, entomologist] role different from what you expected?

*The appropriate role's question will be filled in for each version of the game.

Appendix G

Interview Questions

1. Describe your experience with the game.
2. What did you think of the augmented reality portion (the PDA part)?
3. If augmented reality games were more readily available where would you like to play them. (prompt if needed: parks, schools, museums, etc.)
4. What is the next step you would like to see in the Red Wolf Caper?
5. Which role did you play today? Why did you pick that role?
6. What was your favorite part about the game? What was your least?
7. Do you like to spend time outdoors?