IDEA GENERATION IN GROUP DECISION-MAKING

DURING SCHOOL SHOOTING SIMULATIONS

DISSERTATION

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Doctor of PHILOSOPHY

by

Shelrie Dawn Houlton, M.A.

San Marcos, Texas
August 2013

IDEA GENERATION IN GROUP DECISION-MAKING DURING SCHOOL

SHOOTING SIMULATIONS

Committee Members

Approved:

Sven Fuhrmann, Chair

Mark Fonstad

Alberto Giordano

John Tiefenbacher

Approved:

J. Michael Willoughby
Dean of the Graduate College

FAIR USE AND AUTHOR'S PERMISSION STATEMENT

ACKNOWLEDGEMENTS

I am grateful for the many people who provided guidance and support for this dissertation. I would like to sincerely thank my research advisor, Dr. Sven Fuhrmann, for his supervision on this research and my dissertation committee members, Dr. Alberto Giordano, Dr. Mark Fonstad, Dr. John Tiefenbacher, and Dr. Robert Edsall, for their guidance. I would like to thank all of the research participants who made this work possible. Finally, I would like to thank my partner, Steve Wertheimer, for his encouragement throughout my dissertation work.

This manuscript was submitted on June 3, 2013.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

IDEA GENERATION IN GROUP DECISION-MAKING

DURING SCHOOL SHOOTING SIMULATIONS

by

Shelrie Dawn Houlton, M.A.

Texas State University-San Marcos

August 2013

SUPERVISING PROFESSOR: SVEN FUHRMANN

Increasingly, many policy decisions are made by groups consisting of individuals with diverse educational backgrounds, experience and agendas. Such diversity within a group can lead to a rich tapestry of information on which to build an informed decision, but can also lead to communication breakdown when the diversity creates competition, instead of integration, of viewpoints. This research examines the effectiveness of the design elements of animation, interactivity and agent-based modeling in support of understanding spatial information in decision-making tasks. Small groups consisting of diverse stakeholders are observed using a geosimulation as a tool to aid in understanding complex systems for the purpose of supporting sapatial decision-making. The groups are tasked with choosing additional exits for evacuation of students and staff for potential school shooting scenarios. The groups also use a blueprint in an additional session for the same task for comparison to the geosimulation results. The analysis is based on both the dialogue of the groups and a questionnaire that each participant filled out at the end of each session. Thematic analysis was applied to the dialogue to identify ideas that were developed by the groups for exit placement and Adaptive Structuration was applied to the themes to determine which themes were developed using the geosimulation and the blueprint. A Chi-square test of homogeneity was used to compare the questionnaire answers between the geosimulation and the blueprint. Thematic analysis was also applied to the answers of the questionnaire. Both the geosimulation and the blueprint aided in developing ideas for exit placement during the sessions. The geosimulation sessions resulted in more ideas among more groups than the blueprint sessions. In addition, the groups determined that the geosimulation was more effective for understanding the system, as well as exposing unexpected issues arising from emergent properties of the system, than the blueprint. This supports the use of the geosimulation as an effective tool in aiding decision-making.

CHAPTER 1.

INTRODUCTION

Crisis situations, defined as surprise situations that are seen as a threat to goals and create uncertainty, have always been a part of the human experience (Seeger et al. 1998). Events such as the volcanic eruption of Mount Vesuvius in 79 AD, the U.S. stock market crash of 1929, and the 2004 Indian Ocean earthquake and resulting tsunami are examples of large-scale crisis events. In response to such crises, societies have developed many approaches to preventing and managing these events, such as earthquake detection systems and city-wide evacuation plans. In recent years, the process of crisis management has involved both diverse decision-making groups that help plan for crisis events and technology to aid the groups (Coleman 1995; Creighton and Adams 1998; Grudin and Poltrock 1997; Laituri and Kodrich 2008; Larson and LaFasto 1989; Scott 1999). As crisis events often involve spatial information, such as route planning for evacuation and delivery of supplies, geosimulations, which are high resolution spatial models used to explore ideas and hypotheses about how spatial systems operate, show promise as crisis management tools (Benenson and Torrens 2004; Bradsher-Fredrick 1981; Comptdaer et al. 2007; Duke 1989; Sahli and Moulin 2006). While geosimulations show potential for aiding in the analysis and understanding of spatial systems, some researchers have noted a lack of research focused on understanding the true effectiveness of such new technology (Fabrikant 2001; Sharma et al. 2003; Slocum et al. 2001). Koua, MacEachren, and Kraak (2006) determined that, as new representations of spatial data are created, along with new ways to interact with the visualized spatial data, the usefulness and usability of such tools can only be ascertained by assessing their impact on data exploration and knowledge construction.

This study assesses the extent to which decision-making groups can utilize a geosimulation to understand a crisis event, namely a school shooting, in order to mitigate the situation. The use of this application is compared to a tool that also displays spatial information and is currently used in school crisis plans, blueprints. The geosimulation application is built upon knowledge from the fields of group decision-making, geovisualization, and agent-based modeling.

1.1 Problem Statement

In dealing with crisis situations, small groups are often tasked with making decisions concerning a wide range of issues, such as the best way to evacuate cities during a hurricane, or how best to bring relief to a community after a major oil spill (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2010; Scott 1999; U.S. Army Corps of Engineers 2010). Due to the complexity of the issues, the composition of these groups is often heterogeneous concerning education, background, and interest in the issues. A committee tasked with determining the most effective way to bring relief to a community after a hurricane may be composed of individuals who live in the community, government representatives, and engineers. With such diversity, information exchange between members may become ineffective, due to different agendas, communication styles, and personality types, keeping the group from developing solution options and reaching a decision concerning the crisis situation (Andrienko et al. 2007; Tuler 2000). One approach to addressing issues of group decision-making is to develop applications that enable groups to collectively better understand the information presented to them. While technology designed specifically for group use has been available for decades, most of the available applications are designed to aid in information tasks, such as note-taking and data management. As the amount of data available for any particular event has grown, new technology for viewing, sharing, and analyzing these data is being developed and the appropriateness of its use in group settings needs to be examined (Frey 1999; Slocum et al. 2001). Many crisis events exist that allow testing of such group decision-making applications. One such event, school shootings, is relevant and motivating to a wide range of individuals, including law enforcement, teachers, medical professionals, parents, administrators, and community leaders. This potential pool of participants reflects the wide range of backgrounds that would be found in groups tasked with decision-making in crisis events.

School-shooting situations involve people interacting with one another and their environment in a system that decision-making groups must understand to create solution options. Simulations, which in this context refer to the representation of real systems, have been used to gain insight into such systems (Colella 2000; Katehi, Pearson, and Feder 2009; Penner 2001; Resnick 1996). Many crisis situations are represented by systems that include spatial information, such as evacuation routes, and can be represented within a geosimulation, described by Benenson and Torrens (2004) as a spatial model for exploring spatial systems.

In order to understand the value of a geosimulation for decision-making in such groups, appropriate methods must be selected to develop the geosimulation. One of the ways that the exploration of ideas and hypotheses can take place in the geosimulation is through the actions of agents, representing humans and their behavior. According to Franklin and Graesser (1996), "An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time in pursuit of its own agenda so as to effect what it senses in the future" (p. 5). When the geosimulation incorporates agents, the represented system can depict system elements interacting with the environment of the system. The agents represent the students and shooter of the school shooting scenario. Systems also have properties that emerge through the interactions of the components with the environment (de Smith, Goodchild, and Longley 2007). Agent-based modeling, by representing the interactions of the system's components, can provide a means of representing the emergent properties, leading to a deeper understanding of the system by the users (Resnick 1996).

Geovisualization is a field within the broader field of geography that develops methods and tools to support analysis and visualization of spatial data (Dykes, MacEachren, and Kraak 2005). Two methods from geovisualization that hold promise for development of a school shooting geosimulation to aid group decision-making are animation and interactivity. Slocum et al. (2001) describe animation as a form of dynamic representation in which the display changes continuously while interactivity refers to the ability of a user to control the display and explore the data in the animation. The animation supports depiction of the school and the agents as simple representations of their real world counterparts, providing identification by users. The interactivity allows users to change initial conditions in the geosimulation, such as the locations of the exits and the shooter, as well as visual perspective.

Another component of decision-making is to understand the uncertainty inherent in each option (Andrienko et al. 2007). The three methods selected to develop the geosimulation, agent-based modeling, animation, and interactivity, provide users with tools to test hypotheses within the system of interest to garner feedback for each solution presented (Andrienko et al. 2007; Benenson and Torrens 2004).

1.2 Scope of Study

This study focuses on a geosimulation designed to facilitate effective understanding of the crisis event information to aid in decision-making for groups. Such groups are found in a wide range of settings, including government agencies and corporations, and are made up of individuals from a wide range of backgrounds. This study brings together multiple diverse groups to look at the way these subjects use the methods of the geosimulation to work toward a decision on exit-placement for effective evacuation during a school-shooting scenario. It is hoped that the variety of backgrounds of the participants, such as upbringing, interests, and education, will reflect the variety of backgrounds that are found in such decision-making groups.

1.3 Research Questions

The overarching question guiding this study is: How do the components of a geosimulation impact effective understanding of crisis events to aid decision-making in groups and the group's understanding of the uncertainty in each solution choice, compared to more traditional media, such as blueprints? The following four questions are posed to examine different components of using geosimulations in this context:

1. What are the benefits and limitations of a geosimulation for use in group decision-making?
2. How do the benefits and limitations of a geosimulation for group decision-making compare to the benefits and limitations of the more traditional media of blueprints?
3. How does a geosimulation convey the uncertainty of different solution choices in group decision-making?
4. How can a geosimulation be effectively integrated into existing group decision-making processes?

1.4 Limitations

Decision-making groups are often small and composed of people with a wide range of backgrounds. This study recruits participants from a wide range of backgrounds to reflect the composition of groups that make decisions for crisis events. During the recruitment effort, attempts to coordinate a diverse set of people into test groups had limited results. Diverse schedules and commitments led to fewer groups than originally anticipated, as not all the individuals could meet at a time that worked for a larger number of participants. This smaller number of groups necessitated less robust qualitative methods for data analysis.

The geosimulation developed for this study contains three methods: animation, interactivity and agent-based modeling. Each of these methods promotes understanding of information and data analysis as is evidenced in previous studies (Ogao 2006, Resnick 1996). This study extends those studies to use these methods to develop solutions in group crisis decision-making. This study evaluates neither the quality of the groups' decisions nor the quality of the interactions of the group during their discussions.

1.5 Significance

Group decision-making is often employed to tackle problems associated with crisis situations. In order to develop solutions to these issues, the group members must often understand and analyze complex spatial information. To aid in understanding and analyzing spatial information, many methods have been developed for use by experts (Bell et al. 2006, Fedra and Feoli 1998, Longley and Batty 1997, Rushton 2003). Often these groups are composed of individuals with no expertise in spatial data analysis and need tools developed for the non-expert (Andrienko et al. 2007). In this study, a geosimulation, comprised of the three methods of animation, interactivity and agent-based modeling, is examined to determine the usefulness of these methods to aid groups in understanding and analyzing spatial information for decision-making.

Determination of the effectiveness of the three methods of animation, interactivity, and agent-based modeling for understanding information, data analysis, and the uncertainty inherent in choices in group decision-making settings impacts the development of future group decision-making tools. While a few group decision-making tools dealing with complex spatial data have been studied, none have incorporated all three methods of the geosimulation in this study (Jankowski and Nyerges 2001, Jankowski et al. 1997, MacEachren et al. 2005, Rinner 2006).Some studies have shown the potential for each method to aid individuals in understanding spatial information through data analysis as well as understanding the uncertainty within solution choices (Adrienko et al. 2007, Beneson and Torres 2004, Prior et al. 2002, Slocum et al. 2001, Thompson 2002). The technologies that support these methods require significant resources, which are not usually available to most organizations at this time. If these methods effectively improve crisis decision-making, then there would establish a justification for investment in the resources needed to develop and implement the technologies.

CHAPTER 2.

LITERATURE REVIEW

This chapter examines the use of technology use to aid groups tasked with decision-making. The purpose of this examination is to determine the benefits of a geosimulation for understanding crisis events for group decision-making and the appropriate methods to develop useful geosimulations. The methods to evaluate the usefulness of the geosimulation within groups are also determined.

2.1 Group Decision-Making

Andrienko et al. (2007) note that decision-making processes frequently involve people possessing disparate roles and backgrounds; these may include administrators, politicians, and expert analysts. When groups are formed to discuss issues, the communication and interactions between them are the keys to bridging their differences, so that the knowledge of all participants can be synthesized into effective answers and solutions (B. Fisher 1980; Scheerhorn, Geist, and Teboul 1994; Scott 1999). Unfortunately, the communication process is often hampered rather than enhanced by the differences among individuals as these differences can lead to misunderstandings, a lack of consensus, stalemates, or even intentional "hijacking" of the situation (Fisher 1980; Tuler 2000).

One approach to aiding groups is to develop technologies that improve their understanding of the relevant information. Group-based approaches to decision-making have long been used by corporations (as of 1985, more than 80% of Fortune 500 companies in the United States relied on them), governments (committees and juries), and the medical establishment (health care teams) (Brashers, Adkins, and Meyers 1994; Scott 1999). These groups have fostered the development of technologies that aid in group decision-making. Scott (1999) stated that the 1990s saw a $5.5-$10 billion industry developing technology to support groups, that this technology has been used by several million people, and that it is a key resource in more than 1500 organizations (Scott 1999).

While there have been a large number of new technologies developed to aid group decision-making, these are rarely geared toward data exploration or knowledge construction. Data used in group decision-making are often presented in the form of expert reports, maps, videos, and images with the goal of understanding a particular event (Robinson 2008; Scott 1999). Information in this format rarely supports individual's capacities to explore the information presented to them, as it is often of a static nature, such as in pictures or maps. According to Andrienko et al. (2007), the ability to explore information is an important part of decision-making. This necessitates the development of technology that supports information-exploration and develops group understanding of the information presented. The requirements of such technology are examined in the next sections.

2.1.1 Learning, Communication, and Simulation

In order to reach a decision as a group, members need to understand the information presented to them and reach some agreement about the information. This ability to understand the information as a group requires communication between individuals about the information to develop group ideas, which can lead to solutions and the selection of one option by the group. Examining communication science, Duke (1989) posited that the model of the communication process is limited to the one-way, sender-receiver mode of communication. He concludes that this hinders communication by limiting the receiver to a passive role in the process. He proposes that communication is dependent on the language used and whether the language is spoken, written, emotional (such as art or dance), or technical (such as mathematics). As society increasingly seeks consensus on some policy questions, Duke determines that a language must be developed that aids groups' understanding and communication about complex issues. Duke lists four characteristics determined to be central to any situation in which true communication takes place:

1. The sender must succeed in motivating the receiver before information is transmitted.
2. The receiver must be an active rather than a passive participant in the process.
3. The communication flow (information) must be individualized so that the pace for the receiver is correct.
4. The receiver must have prompt feedback in the dialogue so that messages can be challenged and differing opinions expressed.

These four conditions reflect a new mode of communication as the one-sided talking ‘at’ mode is replaced by talking ‘with’ and discussions have new meaning as they are achieved by the group using their own resources, rather than having the meanings ‘painted’ on the group by outside sources (Duke 1989). Gaming/simulation can be the new language used by groups for complex decision-making because they support the four components of communication for group information-sharing. Gaming/simulation (Duke links these terms to reflect their interchangeability) represents the whole of the phenomenon instead of only parts of the phenomenon of interest. Gaming/simulation employs a symbol set and conventions for their use unique to that particular gaming/simulation in order to support a multilogue (simultaneous discourse among multiple users) (Duke 1989). This conceptualization of a simulation was discussed earlier by Bradsher-Fredrick (1981) and has since been applied as a communication and knowledge-construction application for many different groups (Arias et al. 2000; Arias and Fischer 2000; Jermann 2002; Kumar et al. 2007; Leemkuil et al. 2003; Plaisant et al. 1999; Roschelle and Teasley 1995; Schell and Black 1997; Tao 1999; Vasiliou and Economides 2007). In one experiment by Roschelle and Teasley (1995), participants used a physics simulation to depict the concepts of velocity and acceleration. When a group member expressed an idea concerning the concepts, the idea was explored in the simulation and the participatnts discussed the processes and results. The depiction of velocity and acceleration within the simulation created a common language that aided collaboration, data exploration, and knowledge construction.

Group communication and non-simulation technology has been a popular topic of discussion in the scholarship (Blundell 1997; Creighton and Adams 1998; Finn and Lane

1998; Grudin and Poltrock 1997; McGrath and Hollingshead 1994; Seibold, Heller, and Contractor 1994), as has the use of simulations for data exploration and as educational tools (Becciani et al. 2012; Chen 2002; Grant and Kluge 2005; Keys and Wolfe 1990; Lunetta and Peters 1985; Nocke, Flechsig, and Bohm 2007). The literature, however, lacks studies of simulations as technology that enables a common language within a group to foster collective understanding of information and knowledge construction, both important components of decision-making. Duke's (1989) model explores simulation as a tool that builds a common language within groups trying to understand systems and is therefore employed as the basis for this study.

2.1.2 Uncertainty

Uncertainty is inherent in choices that individuals and groups make. In reaching a decision as a group, understanding the underlying source of uncertainty of each solution option can provide groups with a method of comparing these options. Uncertainty is present in the process of making decisions every day—from decisions about what to eat to decisions about what types of investments to make for retirement. In reaching a decision concerning a particular issue, decision-makers must deal with the uncertainty that is part of each solution option (Carrara et al. 1991; Guzzetti et al. 1999). Uncertainty has often been used in vaguely defined ways, and has been deemed synonomous with the term "risk." These terms must be defined to avoid confusion. Frank Knight (1921) defined uncertainty and, at the same time, distinguished uncertainty from risk in a seminal definition of both terms in 1921. Knight established that risk was present in situations where decision makers are faced with unknown outcomes but have access to previously calculated probability distributions associated with the outcomes. Uncertainty differs from risk, according to Knight, in that the unknown outcomes are not associated with previously calculated probability distributions. This leaves decision makers with no way to compare different choices measurably. Others have expanded on Knight's definitions of both uncertainty and risk (Holton 2004; Hubbard 2007; Kaplan and Garrick 1981; Markowitz 1952). Holton (2004) wrote that "uncertainty is a state of not knowing whether a proposition is true or false" (p. 21) and acknowledged that while some have tried to use probability as a metric of uncertainty (a contradiction of Knight's definition), this approach has been of very limited use.

2.1.3 School Shootings

In order to develop a simulation for groups to use during decision-making, the system to be presented to a decision-making group must be chosen. Duke's (1989) first criterion is that the receiver be motivated to receive information in the communication process. Crisis events, particularly school shootings, are motivating to many individuals, based on the large number of these events that have impacted many different communities and families. Over the last fifty years, the frequency of mass school shootings has increased and these events have been gaining attention (Vossekuil et al. 2002). Vossekuil et al. (2002) noted that while this type of violence in schools is less frequent than those of a directed nature, such as gang violence or personal vendettas, the often random nature and large-scale devastation of these events create a fearful environment that has implications at the national level. Since 1966, more than 100 incidents in which an individual or group of individuals have entered a school and directed violence at one or more individuals, resulting in injury or death have occurred in the United States (Vossekuil et al. 2002; Wikipedia 2010). School shootings are currently a hot topic that psychologically affects a large number of people, including law enforcement, psychologists, medical personnel, and parents, and therefore generate motivation for receiving information about the topic. This motivation determines the crisis event, a school shooting, as an appropriate system for groups to understand in order to generate solution ideas for mitigating the situation.

2.2 Simulation

When determining the methods needed to develop a simulation, the particulars of the system that the simulation represents should be determined. The school-shooting scenario, with individuals, their behavior, buildings, and the interactions among these components, can be represented by methods from the fields of modeling in geography and geovisualization. These methods can also represent system behavior apparent only through the interactions of the components, known as emergent behavior, and the uncertainty of different solution options. This information is important in order to give groups the ability to understand a system at all levels for decision-making purposes as well as to propose solution options for decision-making.

2.2.1 Agent-Based Modeling

Crisis events, such as school shootings, often involve spatial information and can be effectively represented by a geosimulation. Geosimulations have developed from the fields of modeling and geography and are described by Benenson and Torrens (2004) as "concerned with the design and construction of object-based high-resolution spatial models, using these models to explore ideas and hypotheses about how spatial systems operate" (p. 1). Many different types of modeling exist within the field of Geography, such as mathematical models describing the changing spatial dynamics of sea urchins within kelp beds (Lauzon-Guay, Sebastien, and Scheibling 2010), cellular automata models describing spatial dynamics for population growth of a predator/prey system (Couclelis 1988) and agent-based models that are used to understand systems with agents with mobility, such as migration patterns between neighborhoods (Sakoda 1971; Schelling 1971), voting patterns (Schweitzer et al. 2002) and traffic jams (Wahle et al. 2002; Wylie et al. 1993).

Agent-based modeling shows potential as an appropriate method for representing a school-shooting system. Agent-based models are generative models (bottom up) in which agency is represented by heterogeneous automata involved in decision-making and interaction with one another through space and time (Benenson and Torrens 2004). The generative model is used to create a representation of a system (such as a transportation system) using the basic elements (such as roads and vehicles) in order to observe the interactions taking place between these basic components. School shootings involve individuals that must have mobility and interact with the environment, requirements for which agent-based modeling is designed.

2.2.1.1 Emergent Phenomena. The scenarios involving crisis management that require group decision-making, such as disease control and hurricane evacuation, are often operating in the context of complex systems. Katehi, Pearson, and Feder (2009) stated that a system can generally be described as a collection of interacting pieces. For example, a transportation system can be looked at as the collection of all things, such as railways, roads, and motorcycles, that aid in moving people and things from one place to another (Katehi, Pearson, and Feder 2009). Katehi, Pearson, and Feder argue that a system is also more than the sum of its parts and that to understand the system requires an understanding of not only the parts but also the interactions of these parts.

As de Smith, Goodchild, and Longley (2007) contend, the stable macroscopic patterns resulting from individual entities interacting locally create the emergent phenomena of a system, making emergent behavior a case of the whole being more than the sum of the parts with properties that are not coupled to the properties of the system's parts. Emergent phenomena can be a driving factor in some of the behavior of systems, yet can be difficult to understand from the properties of the individual components. One set of studies shows that individuals tend to view the causes of system behavior to be either a central plan or a single cause, while other studies reveal that individuals tend to classify scientific phenomena conceptually into inappropriate ontological categories and therefore create misconceptions about the phenomena (Chi 2005; Chi and Roscoe 2002; Reiner et al. 2000; Silk and Schunn 2008; Slotta, Chi, and Joram 1995; Slotta and Chi 2006).

In searching for tools to improve our understanding of emergent phenomena in systems, some researchers have used simulation to help illustrate the phenomena. A number of studies show that two main types of simulations are used in teaching the principles of emergent properties, one consisting of life-sized, participatory simulations (such as role-playing); the other consisting of software environments (Colella 2000; Katehi, Pearson, and Feder 2009; Penner 2001; Resnick 1996; Resnick and Wilensky

1998; Wilensky and Reisman 2006; Wilensky and Resnick 1999). While both types of simulations are helpful, the studies show that the software environments are the most effective, allowing the students to explore and manipulate data more easily. Using these dynamic simulations also make the connections between the levels of a system more apparent, which helped in the identification and understanding of emergent properties.

Some simulations represent phenomena requiring mobility in the basic elements, such as a simulation of humans evacuating a building. The explicit depiction of the interactions among automata makes agent-based modeling an appropriate method for understanding emergent phenomena. In a study by Resnick (1996), Starlogo (an agent-based simulation language) is used by high school students to understand how the behavior of traffic jams emerged from a transportation system. The cars are designed to move through the system at different speeds (the speed of the cars change based on the traffic conditions) and the students are allowed to run multiple simulations that resulted in traffic jams. In response to the traffic jams, the students are tasked with deciding on solutions to avoid traffic jams. The students reason that certain conditions should be changed in order to minimize traffic jams but, when applied, they discover that their reasoning did not result in fewer traffic jams. The use of agent-based modeling in the simulation allows the students to manipulate the rules regulating the speed of the cars to understand the effects these changes have on the overall system. The method of agent-based modeling to support active participation by the users and to individualize the flow of information reflects Duke's (1989) second and third criteria. The students are also provided with immediate, constructive feedback on their decision-making process supporting Duke's fourth criteria.

Many of the systems that are studied using an agent-based model within a simulation focus on analyzing, exploring, and sometimes predicting the emergent properties of the systems. These emergent properties are not tied to the information of the agent or environment, but result from interactions between those components and are not necessarily extrapolated from the initial information of the components. In order to understand a system to make decisions, groups would need to understand information at several levels of the system, not just at particular points in time and space of the system's information.

2.2.2 Uncertainty and Agent-Based Modeling

In understanding uncertainty, methods need to be selected that aid in this process. Thompson (2002) asserts that information concerning solution choice is often presented as a statistical analysis, yet leaves out much of the rich information concerning the processes that create the probabilities. If these processes could be better understood by decision-makers then the uncertainty of solution options could be minimized (Thompson 2002). Using the method of agent-based modeling can aid in understanding the processes of a system and making predictions about future states of systems (Benenson and Torrens 2004; Epstein 2002; Gilbert and Terna 2000). One recent study tests whether agent-based modeling can aid in understanding the rate of robbery in a city by attempting to accurately generate the statistics and processes of robbery of a city (Groff 2007). The system consists of a virtual city in which visual representations of the various agents move through virtual space. By showing the interactions of the basic elements of the system, the method of visualizing agent-based modeling depicts the processes that are associated with these interactions, which could promote a better understanding of the outcome of different choices.

2.3 Geovisualization Theory

Agent-based modeling provides a method to represent the dynamics of a school shooting system, but does not determine the presentation of the information to users. The field of geovisualization provides a diverse range of methods of representing spatial information.

Geovisualization is a developing field that builds upon approaches from several disciplines, including cartography, image analysis, information visualization, and exploratory data analysis to create methods and tools that support geographic data visualization, analysis, synthesis, and presentation (Dykes, MacEachren, and Kraak 2005). Slocum et al. (2001) states that an important feature of geovisualization is the support of geospatial data exploration to understand relationships in space and time based on patterns that may be hidden in the data.

The field of geovisualization offers methods to visualize spatial data. Three such methods are geometrically transformed, iconic, and dense pixel displays (Keim, Panse, and Sips 2005). Determining which method of geovisualization to use to design a geosimulation requires understanding the context of the information. Within the field of geovisualization, MacEachren and Kraak (1997) designed a cube that emphasizes the development of maps based on the purpose of the information within the map. Map development is described as three dimensions with axes that express the level of interactivity, the size of the audience using the map, and the level of analysis for which the map is meant (Figure 1). Extending this concept, MacEachren and Kraak's cube can inform the development of a geosimulation.

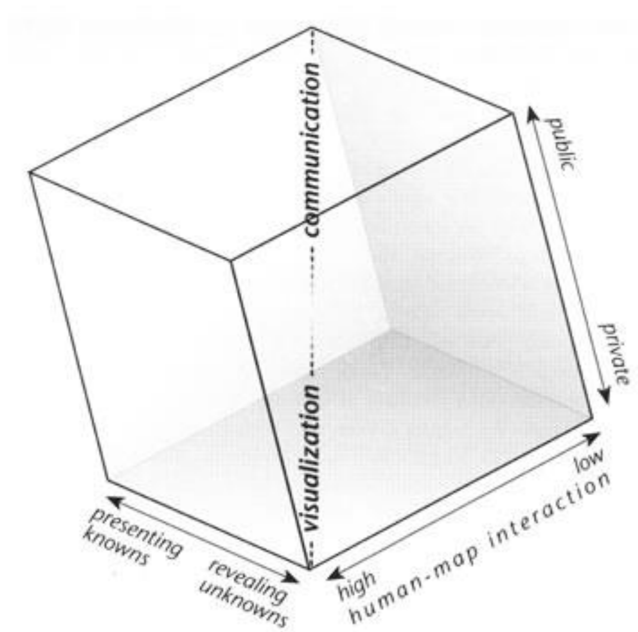

Figure 1. MacEachron and Kraak (1997, p. 337) Map Cube.

MacEachren and Kraak (1997) presented four strategies of map use that are reflected in the three axes of the cube. These strategies are visualization to explore, visualization for analysis, visualization for synthesis, and visualization for presentation. Starting with exploration and proceeding to presentation, the axis of audience size goes from private to public, changing from individuals to small groups in visualization for synthesis and then large groups in the presentation strategy. The exploration strategy also represents the highest level of interactivity of any strategy. Moving along this axis, the strategies become less interactive from analysis, synthesis, and finally presentation. The third axis reflects how the data are examined. The exploration strategy involves raw data that are examined to understand relationships among variables. The analysis strategy moves along the data relationship axis to understanding relationships between data sets of known information, while synthesis focuses more on extracting patterns from multiple known data sets and then displaying the information coherently. Presentation falls on the far end of the data relations axis, which allows for minimal analysis but can elicit new insight through presentation of data findings.

The requirements for the geosimulation would lie closest to the synthesis strategy within the map cube. The geosimulation presents multiple known data sets represented by a shooter, students, and a school in order to understand patterns in the interaction of these data sets in space and time. These types of data sets encourage visualization methods that display each set as an object in order to view the relevant data interactions. The users are small groups and the geosimulation would require a level of interactivity with the data that is approximately half way down the interaction axis, allowing interaction with the datasets (e.g., the location of the shooter) not the data composing the data sets (e.g., the shooter's behavior). Two methods from geovisualization, animation and interactivity, show potential to meet these requirements by depicting the data sets as individual objects, with the raw data embedded in the object and allowing users to interact with the visualized object level data.

2.3.1 Interactivity and Animation

Slocum et al. (2001) determined that animation can aid in the understanding of data and that exploration of the data requires methods that incorporate a high degree of interactivity. They argue that animation is “natural for depicting temporal data because changes in real world time can be reflected by changes in display time” (p. 6).

While some research shows promise in the method of animation for depicting space-time processes (Harrower 2002; Midtbø, Clarke, and Fabrikant 2007; Ogao 2006; Slocum et al. 2001), Slocum et al. (2001) also noted that studies comparing the effectiveness of animated maps to that of static maps have yielded mixed results, indicating the need for more research on the conditions under which animated maps can be effective.

In a review of empirical animation research, Tversky, Morrison, and Betrancourt (2002) found that animations are often too complex and too fast for subjects to perceive the presented information accurately. Harrower (2003) determined that if an animation is to convey information effectively, then the information should be well organized and the animation should contain as few details as possible. Slocum et al. (2001) admit that, while some animations, such as videotapes, permit little interaction with the information contained in them, greater understanding might be achieved by giving the user the ability to control his or her exploration of the data in a variety of ways. Sando, Tory, and Irani (2009) state that one of the goals of animation is to facilitate a person’s understanding of a given object’s true structure and its relation to the surroundings. Animation therefore promotes perceptual constancy, defined by Robertson, Card, and Mackinlay (1993) as a perceptual phenomenon that preserves the identity of an object, even when it is seen under varying conditions, such as perspective, distance, or lighting.

To create an animation that depicts spatial-temporal processes more effectively than the alternative of static images, interactive displays have been explored to examine the effect on the ability of users to extract information better from the animation. In a study by Ogao (2006), three types of map animations were tested. The first was an animated map in which subjects passively watched the animation; the second condition presented an animated map that gave subjects basic media player control (i.e., navigation and orientation tools); while the third condition gave subjects the same amount of control as the second condition, but added an automated intelligent view that alerted subjects to "interesting patterns, trends or anomalies" (Ogao 2006, p.1). The results of this study showed that most users preferred the interactive and inference-based animations, that hypotheses concerning the data were made more often by those using the inference animation, and that the next largest number of hypotheses were made by those using the interactive animation. Another note is that the intelligent viewing tool prompted exploration more often than the other tools. Ogao also noted that the inability to control the dynamic display in such areas as stop, play, and pause resulted in frustration in the subjects. Sando, Tory, and Irani (2009) also found that 3D, rotatable displays resulted in subjects accomplishing spatial positioning tasks more effectively than with static 2D/3D displays. These results indicate that animation, coupled with some type of interactivity with the animation, more effectively supports data exploration and understanding, which aligns with the design requirements of the cube concerning users' ability to interact with the spatial information.

The combined methods of animation and interactivity support two of Duke's (1989) criteria. Animation and interactivity support an active role for the users during data exploration (criterion 2) and allow the users to create the pace of information flow to meet individual needs (criterion 3).

2.3.1.1 Second Life. In order to incorporate animation and interactivity into the geosimulation, an appropriate platform needs to be determined. Three-dimensional virtual worlds provide both animation support and interactive features that make them attractive as the platform for a geosimulation. When examining 3D virtual platforms, a wide range of options are considered. Numerous websites such as Active Worlds, Free Realms, Cloud Party, and Twinity allow a level of development, but Second Life offers the most flexibility in development for animation and interactivity (ArianeB 2011).

Crooks, Hudson-Smith, and Dearden (2009) describe Second Life as a powerful virtual and visual world containing an internal event-driven scripting language that can be used to assign rules of behavior to objects and when these objects interact, they create dynamic behavior. Access to more than 3000 built-in functions, including communication between objects, collision detection, and physics simulation, as well as the ability to build or sculpt any object and import textures and graphics provides a rich, immersive, visual, multi-user environment (Crooks, Hudson-Smith, and Dearden 2009). Many companies, government organizations, and academic institutions, including Nature Publishing, NOAA, NASA, Texas State University–San Marcos (Figure 2), Rutgers University, IBM, Microsoft, and AIT have created a virtual space in Second Life which can be visited by avatars (virtual representations of human users). With the creation of an avatar, every Second Life human user can move, via his or her avatar, through the virtual world and interact with objects and other avatars. Crooks, Hudson-Smith, and Dearden stated that, as of 2009, Second Life had more than 14 million registered users and that each week more than 400,000 individuals used the application. Since it was launched in 2003, Second Life's virtual space grew from a few kilometers to more than 750 km^2 (Ondrejka

2007). Although the world is hosted by Linden Labs, its content has been created by users, who spend a total of 23,000 hours per day creating everything from clothing to houses (Hoff 2006). In addition to objects, residents create a wide range of topographical features, such as rivers, mountains, and fields (Crooks, Hudson-Smith, and Dearden 2009).

Figure 2. Texas State University- San Marcos Campus in Second Life.

***2.3.1.2 Uncertainty, Interactivity, and Animation*.** In order to determine the most effective approach to aid groups in understanding the uncertainty present in the choices presented to them, appropriate methods need to be included in the geosimulation that address this issue. When groups are tasked with decision-making, the uncertainty with regards to solution options becomes an important factor in the group's ability to reach a decision. Andrienko et al. (2007) comment that, in many decision-making processes, choosing between options requires, at minimum, an understanding of the nature of the choices presented and why they are options, as well as the uncertainty and benefits inherent in them. Andrienko et al. indicate that using visual representations and interactive visual interfaces in “what if?” testing of options can be an effective way of communicating information concerning those options and their outcomes. In addition, some studies have shown that the use of images assists in the process of option assessment (Prior et al. 2002).

2.4 Analysis Methods

In order to reach decisions for any problem, groups must share ideas for the development of creative solutions leading to decisions (Paulus and Yang 2000). These ideas must be identified to determine if the group is developing solutions for a decision to the problem. One method of identifying ideas in group interactions is thematic analysis (Leininger 1985). Another method, Adaptive Structuration Theory (AST), is used to identify which ideas relate to explicit use of the technology by the decision-making group (Chin, Gopal, and Salisbury 1997). AST also identifies the attitude of the group towards the technology, a factor in determining if the group uses the technology during discussions (Chin, Gopal, and Salisbury 1997).

2.4.1 Thematic Analysis

Thematic analysis is a method to find patterns, or themes, in qualitative data (Boyatzis 1998). This type of analysis can be found in fields such as art, psychology, astronomy, mathematics, biology, cultural anthropology, history, sociology, literature, physics, chemistry, political science, and economics (Crabtree & Miller 1992; Denzin & Lincoln 1994; Silverman 1998). In order to determine relevant themes in the data, such as solution ideas, the researcher must have knowledge of the subject matter to recognize what is important, give it meaning and conceptualize the observations (Boyatzis 1998; Leininger 1985; Strauss and Corbin 1990). To achieve this knowledge, the researcher must become familiar with the dialogue in order to search for any patterns related to topics of interest to the researcher (Aronson 1994). Aronson (1992) uses thematic analysis to understand the experiences of families within the juvenile justice system. Two relevant patterns, or themes, from the interviews with one family arose immediately, prompting the researcher to classify all dialogue relating to those patterns to develop a richer look at each particular pattern (Aronson 1992). The next step is to compile information relating to the theme, based on the identified patterns, from the units which are comprised of "conversations, topics, vocabulary, recurring activities, meanings, feelings, or folk sayings and proverbs" to create a deeper understanding of the meaning behind the patterns (Taylor and Bogdan 1989, p. 131). In addition to identifying themes in the dialogue, feedback from the participants can strengthen the understanding of the themes (Aronson 1994).

2.4.2 Adaptive Structuration Theory

When developing solution ideas for crisis event mitigation, a group using technology to aid in the decision-making process can use information other than that provided by the technology, such as previous experiences, to formulate a solution idea. In order to understand the use of a simulation by groups to create solution ideas, a method of analysis is selected that allows understanding of the impact of the technology on a group's ability to understand information and develop solution ideas. AST provides a method of identifying the solution ideas that develop through the explicit use of the technology by the group. AST also provides a method to determine how useful the group perceives the technology to be to its understanding of the information.

Technology that aids groups in decision-making is developing at an accelerated rate, requiring users to adapt constantly and learn new information. In order to understand the effectiveness of new technology in group decision-making, some researchers in the information technology field are building their studies on the theoretical foundation of AST (Kirwan, Golden, and Molloy 2007; Ruël 2009; Tan and Sedera 2007). Chin, Gopal, and Salisbury (1997) explain that AST grew out of Anthony Giddens's Structuration Theory, which rejected the extreme viewpoints in the agency-structure debate. Giddens emphasized that, while institutions constrain human action, human action also influences and changes institutions (Chin, Gopal, and Salisbury 1997). Giddens's theory has been adapted to many different uses, including AST, which DeSanctis and Poole (1994) applied to the study of information technologies (Chin, Gopal, and Salisbury 1997). DeSanctis and Poole modified Structuration Theory to reflect the effect human action has on technology, and the resulting effect that technology has on human action (Figure 3).

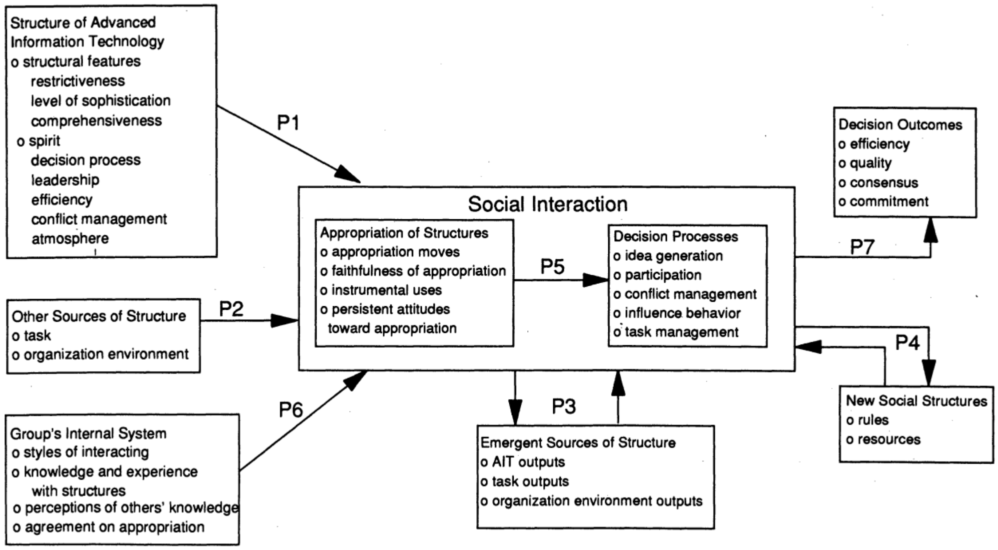

Figure 3. Summary of Major Constructs and Propositions of AST (DeSanctis and Poole 1994, p. 132).

Chin, Gopal, and Salisbury (1997) state that the central aspect of AST is the process of creating and maintaining a social system by the group when it applies the structures (the rules and resources) found within the technology, organizations, culture, etc., as well as the group members' knowledge. This process is called *structuration.* The available, but not yet applied, structures are called the "structural potential," while the structures in use are called the "applied structures". Different groups appropriate different structures and the appropriation is characterized by four constructs (DeSanctis and Poole 1994). The first construct is *attitude*, which reflects the group members' views of the technology. A user can have a positive, negative, or neutral view of different aspects of the technology. The second construct is the *appropriation move*, which reflects how the subject uses the technology, and there are several types, which are summed up in Table 1. The third construct is *faithfulness*, which is a measure of how close the group's uses of the structures are to the uses their designers intended them to have. The fourth construct is *instrumental uses* and reflects the subject's purpose in using a particular aspect of the technology. Examples of instrumental use are using the technology for accomplishing a task or a power move.

Table 1. Summary of Types of Appropriation Moves

Direct Use (structure is preserved)	Direct appropriation	
	1a	explicit
	1b	implicit
	1c	bid
Relate to other Strucuture (structure is interpreted or reinterpreted)	Substitution	
	2a	part
	2b	related
	2c	unrelated
	Combination	
	3a	composition
	3b	paradox
	3c	corrective
	Enlargement	
	4a	positive
	4b	negative
	Contrast	
	5a	contrary
	5b	favored
	5c	none favored
	5d	criticism
Constrain the Structure (structure is interpreted or reinterpreted)	Constraint	
	6a	definition
	6b	command
	6c	diagnosis
	6d	ordering
	6e	queries
	6f	closure
	6g	status report
	6h	status request
Express Judgements about the Structure	Affirmation (structure is accepted)	
	7a	agreement
	7b	bid agree
	7c	agree reject
	7d	compliment
	Negation (structure is rejected or ignored)	
	8a	reject
	8b	indirect
	8c	bid reject
	Neutrality	

(Source: DeSanctis and Poole 1994, p. 135).

Only the first two constructs are examined in this study. The third construct, faithfulness, is not examined as the groups are required to perform a task from the beginning that the technology is designed for and are not given freedom to perform alternative tasks. This study does not examine the focus of the group's use of the technology or instrumental uses, such as using the information as an aid to the task compared to use as a power grab in the group, as the group dynamic is beyond the scope of this study.

2.5 Summary

The development of a geosimulation resulted from two main questions:

1. What type of technology supports effective understanding of information, data exploration, and understanding of solution uncertainty within group decision-making?
2. How does one measure the effect of a geosimulation on the understanding of information, data exploration, and understanding of solution uncertainty within group decision-making?

These questions were the foundation of this literature review and established the direction of the research.

In exploring the first question, a geosimulation was determined to be an appropriate form for the technology to be tested by groups in decision-making. As indicated by Scott (1999), technologies have been used by large numbers of groups to aid in their decision-making tasks for many decades. While these groups have used many types of technologies, most have not focused on data exploration or knowledge construction, an important component of decision-making (Andrienko et al. 2007). Duke

(1989) describes a technology that can be used as a common language for groups in order to explore information. This technology is a simulation, which presents a holistic view of any phenomena of interest. When attempting to understand how spatial systems, such as evacuation routes, work in emergency situations, a geosimulation can depict the spatial information as well (Benenson and Torrens 2004).

From examining the first question, methods appropriate to developing the geosimulation were chosen for this study.. These methods were selected based on their ability to support the requirements of a simulation as put forth by Duke (1989) to represent the system accurately and to illuminate the uncertainty in solution options. Duke's requirements are:

1. The sender must succeed in motivating the receiver before information is transmitted.
2. The receiver must be an active rather than a passive participant in the process.
3. The communication flow (information) must be individualized so that the pace for the receiver is correct.
4. The receiver must have prompt feedback in the dialogue so that messages can be challenged and differing opinions expressed.

The first criterion can be supported by depicting a crisis situation, such as a school shooting, that is relevant to the stakeholders of the decision-making group. The methods to support Duke's (1989) second, third, and fourth criteria for a simulation were informed by the literature review. A crisis situation often involves spatial information and can be represented by a geosimulation, a type of model representing a spatial system. From the modeling literature, agent-based modeling was chosen as a method to depict mobile agents who interact with their environment. The field of geovisualization contains methods that can support representation of spatial information. MacEachren and Kraak's (1997) cube provides a process of determining the requirements of methods to depict spatial information. Through this process, animation and interactivity were chosen to represent object level information with user interaction.

The second and third criteria are both supported through the methods of animation and interactivity. Animation supports a depiction of data through time so that changes can be seen as they happen in real world time (Slocum et al. 2001). Incorporating interactivity with animation supports individual exploration of the data (Ogao 2006; Slocum et al. 2001). By depicting the data through time with the ability to explore the information independently, these two methods support active participants (criterion 2) and individualized information flow (criterion 3).

Agent-based modeling, a method of modeling in which automata are involved in decision-making and interaction with one another through space and time, is employed in models requiring mobility in the basic elements (Benenson and Torrens 2004), which is a system requirement for school shooting systems. Agent-based modeling is a method that is effective at representing emergent phenomena (Resnick 1996). Understanding emergent phenomena, which are the macroscopic patterns resulting from individual entities interacting locally, is fundamental to understanding a system as a whole (de Smith, Goodchild, and Longley 2007), a second system requirement. The incorporation of agent-based modeling supports Duke's (1989) second, third, and fourth criteria by creating an active participant, individualizing the information flow, and creating feedback to opinions through "what if?" scenarios with agents.

Uncertainty is an important component of choices in decision-making and in crisis situations, such as a school shooting (Carrara et al. 1991, Guzzetti et al. 1999). Understanding the uncertainty associated with the different choices can aid groups in choosing between the options. All three methods that support the Duke (1989) criteria for a simulation also support understanding the uncertainty associated with different choices in decision-making. Andrienko et al. (2007) indicate that animation and interactivity can aid in “what if?” testing to try different options to determine their outcome. Agent-based modeling also supports this testing for participant exploration of solution options (Thompson 2002).

From examining the second question, methods appropriate to test a group’s use of the geosimulation to generate solution ideas during decision-making were chosen for this study. Two methods are determined to satisfy this requirement, thematic analysis and AST. The first method, thematic analysis, supports identification of ideas generated by a group during discussion. The second method, AST, supports identification of which ideas are developed through explicit use of the geosimulation, as well as identification of the attitude of users towards the technology.

CHAPTER 3.

METHODOLOGY

3.1 Developing a School Shooting Scenario

A geosimulation must be based on a real system representing a crisis situation in order for groups to test the effectiveness of the methods. This application is used by groups that are working to decide the best placement for a limited number of exits for evacuation during a school-shooting scenario. The event is complex and understanding this event requires input from many different people, such as school administrators and teachers, law enforcement officers, lawmakers, psychologists, and parents. In addition, the choice of exit placement is situated within uncertainty about the effectiveness of any placements.

The school-shooting scenario is depicted using agent-based modeling. The victims and shooter are visually represented by agents with behavior appropriate to each. Using this technique supports Duke's (1989) second, third, and fourth criteria as described above. The agents and the school environment, such as the buildings and furniture, are animated with an interactive interface so that users can view the evacuation processes and can change the information, such as placement of exits and the shooter, in the scenario. Including these two methods supports Duke's (1989) second and third criteria.

The following sections detail the implementation of the methods described in Chapter 2. The implementation of the methods results in the development of a school shooting geosimulation, analysis of dialogue data, and development of a questionnaire and analysis of the resulting data.

3.1.1 Human-centered Design

In order to implement a geosimulation using the methods of animation, interactivity and agent-based modeling, a software design process is chosen. The process used in the development of the geosimulation is human-centered design.

"Human-centered design," also known as "user-centered design," is the name of a design philosophy that incorporates users into the design process, using prototypes and giving feedback on the usefulness of applications (Baseline 2000). The benefits of using a human-centered approach include increased productivity by users, reduced errors by users, reduced training and support for users, improved acceptance by users, and enhanced reputation of designers (Maguire 2001; Slocum et al. 2001). In the past, the methods used to achieve a structured approach to human-centered design were not formalized. Now several ISOs (standards created by the International Organization for Standardization) exist to create a framework for such a design (Maguire 2001).

Maguire (2001) lays out five activities (Figure 3) that are the foundation for usability in a human-centered design process: (1) plan the human-centered design process, (2) understand and specify the context of use, (3) specify the user and organizational requirements, (4) produce designs and prototypes, and (5) carry out user-based assessment. Each activity has a suggested set of methods to encourage the inclusion of users at every step of the design (Figure 4).

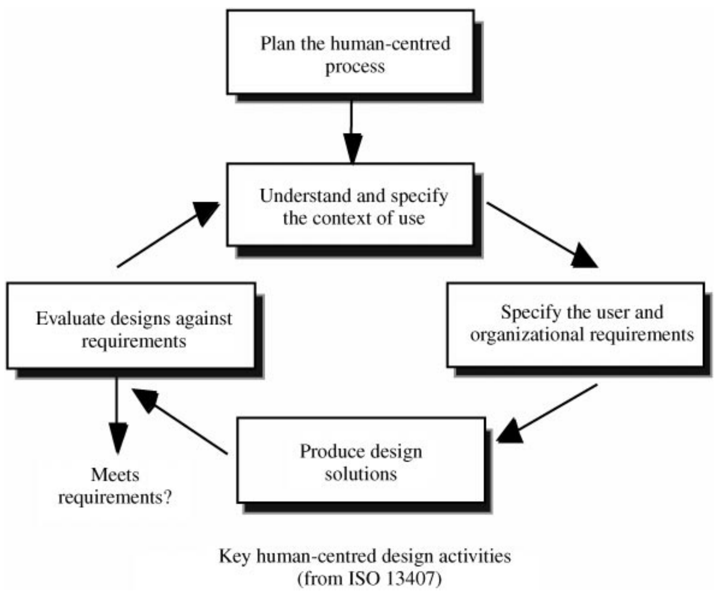

Figure 4. Human-Centered Design Components
(Source: Maguire 2001, p. 589).

The purpose of this study is to examine the effectiveness of the design elements of a geovisualization to promote understanding of information by small, decision-making groups. There are numerous approaches to software design, such as the Waterfall Model, Prototyping, or the Spiral Model (Van Vliet 2000). The human-centered design process is chosen as this approach involves the human element within software design, instead of developing software in isolation. This method uses an iterative process to improve an application for a particular use. The research described here uses a single iteration, as limited resources (limited access to subjects and technology) restrict the study. Participants were recruited from a wide range of backgrounds for experimental sessions to reflect the reality of potential user groups. The equipment used includes a personal computer, a projector and screen, as well as space in the Department of Geography at Texas State, in participants' homes, and at a government facility.

***3.1.1.1 Planning the Human-centered Design Process*.** Two approaches are suggested for this first step (planning the human-centered design process). These two approaches are usability planning and scoping and usability cost-benefit analysis (Battleson, Booth, and Weintrop 2001; Maguire 2001). The purpose of the methods in this process is to discover the needs of the users, the functionality of the geosimulation that fits these needs, and the costs and benefits of implementing the study to obtain this information.

Since the resources needed to apply either of these methods are beyond those available for the current study, this step was modified. Instead of applying one of the two suggested methods, a literature review was used to fulfill the purpose of this step, to discover the needs of the users and the functionality of the application to fit these needs. The users in this study are a group assembled to discuss a crisis scenario (a school shooting) and make a decision concerning effective evacuation (placement of exits). To achieve this goal, the group must understand the system presented to it and members must communicate their ideas to one another through collective exploration of the potential solutions (Andrienko et al. 2007; B. Fisher 1980; Scheerhorn, Geist, and Teboul 1994; Scott 1999; Tuler 2000). The literature review reveals that three methods (agent-based modeling, interactivity, and animation) can aid the group in accomplishing these tasks. The first and second methods, animation and interactivity, work together to promote exploration of the data for knowledge construction and understanding the uncertainty associated with the solution options (Andrienko et al. 2007; Prior et al. 2002).

The third method, agent-based modeling, promotes understanding the emergent behaviors of systems (the school shooting) and the uncertainty associated with different outcomes of competing solution options in decision-making through "what if?" testing of ideas (de Smith, Goodchild, and Longley 2007; Katehi, Pearson, and Feder 2009; Resnick 1996; Thompson 2002).

***3.1.1.2 Understanding and Specifying the Context of Use and Specifying User and Organizational Requirements*.** The second step is to understand and specify the context of use (Battleson, Booth, and Weintrop 2001; Maguire 2001). Maguire (2001) suggests some approaches for accomplishing this activity including the identification of stakeholders, a context-of-use analysis, and surveys of existing users. The purpose of these approaches is to provide information on the range of users and the environment in which they perform tasks.

The third step is to specify the user and organizational requirements (Maguire 2001). The purpose of the approaches in this step is to elicit both user and organizational needs concerning task performance, so that designers can address these needs in the system development process. Approaches like stakeholder analysis, user-requirements interviews, and focus groups have been suggested for this step.

These two steps were combined and refer to gathering information on specific settings, such as the lighting in the room where the users of the technology will work or the company rules relating to the sharing of information. This research is not associated with particular users or institutions, so the information for these two steps is minimized. The users at this stage are generally identified as people with diverse backgrounds and agendas(e.g., parents, teachers, policy-makers, and law enforcement agents) (Andrienko et al. 2007; B. Fisher 1980; Scheerhorn, Geist, and Teboul 1994; Scott 1999). Context of use and organizational requirements were determined through the analysis of school emergency plans as well as an interview with a domain expert (Arkansas Safe School Initiative 2010; Chaminade College Preparatory High School 2010; Commonwealth High School 2010; Fred Fifer III Middle School 2010; Los Angeles Unified School District 2010; Minnesota Department of Public Safety 2010; Nicoles 2010; Tazewell Elementary School 2010). The institution modeled in this study was a generic school. The school needed effective evacuation choices. At this time school evacuation plans are limited to generic evacuation plans, binders containing emergency numbers, and sometimes blueprints or hand-drawn maps.

3.1.1.3 Producing Designs and Prototypes**.** The fourth step is to produce design solutions (Gasson 2003; Gersh, McKneely, and Remington 2005; Maguire 2001; Rauschert et al. 2002). The approaches suggested for this activity include brainstorming, designing guidelines and standards, storyboarding, and software prototyping. These provide design solutions to user needs as well as organizational and environmental needs.

In this step, producing designs and prototypes, two methods are used. Using brainstorming, many ideas are generated concerning how to implement a geosimulation that contains the three methods mentioned in step 1 and that could be used by diverse groups to aid in communication and decision-making as defined in step 2. The ideas for the implementation of the geosimulation are then compared to existing technology to determine feasibility. The solution is a geosimulation within Second Life, a free program that supports animation, interactivity and functionality for agent-based modeling development. The second approach is software prototyping. In this approach, the geosimulation is created for the experimental sessions with subjects.

The ultimate purpose of the geosimulation is to test whether it facilitates group understanding of information and decision-making as well as understanding the uncertainty associated with different choices. For this research, the geosimulation should mimic a school shooting scenario well enough to test the ability of the application to aid a group in understanding the scenario and explore ideas. To this end, the necessary requirements are that the users recognize the system as a school-shooting event and recognize the interactions between the basic elements.

To determine the basic elements to include in the geosimulation, literature describing school shooting events was examined. While there is a wide range of literature on school shootings, most deal with identifying emotional behavior leading to such violence, the emotional impact of the shootings, and effective methods of helping victims of such events deal with their emotions (Cairns et al. 1988; C. Fisher 1993; Olweus 1978; Perry, Kusel, and Perry 1988; Schwartz 1993). The school-shooting event has obvious components, such as the shooter, the victims and bystanders, and authority agents, such as school staff, negotiators, and police officers and a school building (Nicoles 2010). Beyond these components, the important parameters and variables are less obvious. Few studies actually try to discover common elements of school shootings and only one such study has been published (Vossekuil et al. 2002). Many of the findings in the Vossekuil et al. (2002) study indicated little commonality across the attacks, but a few connections were discovered. Most of the attacks lasted less than an hour and, because of this small window of time, few of the events were concluded by police intervention. Traditional training for officers initially responding to such incidents involves learning how to contain the scene and how to wait for officers with specialized training to arrive to deal with the situation ("Police Tactics, Training Changing" 2010; "Columbine High School" 2010). The lack of law enforcement in the crucial moments at the beginning of attacks, which is when most violence occurs, indicates that law enforcement is not an obligatory element for a school-shooting scenario that focuses on effective evacuation during the incident ("Police Tactics, Training Changing" 2010; Nicoles 2010; Vossekuil et al. 2002).

Authority figures, such as a principal or a member of the school staff, are often associated with school shooting events. While authority figures who work at the school would be present, many of them would not be able to deter the attacker from violent actions and would likely become victims themselves (Vossekuil et al. 2002). Therefore, school staff and students are grouped together and classified as potential victims.

An important variable in the model is the action of the victim agent. As individuals become aware of the shooter in the school, they might choose to barricade themselves inside a room or try to exit the space before encountering the attacker. Their decisions would be based on a multitude of elements in the school environment, including presence of the attacker or the availability of an exit.

An important factor of this system is that the environment should be familiar to the agents within it. Both the potential victims and attacker are aware of the exit locations, the rooms that offer protection, and navigation options through the environment to avoid unknown areas.

3.1.1.4 Carrying Out User-Based Assessment. The last step, carrying out a user-based assessment, is to evaluate how well the design elements satisfy user requirements (Gasson 2003; Maguire 2001). The approaches in this process provide feedback from users after they have used the application. These approaches include participatory evaluation, heuristic or expert evaluation, controlled testing by users, and satisfaction questionnaires.

In this final step, two approaches were used to evaluate the software from the users' standpoint. The first method was controlled user-testing, which involved system trials in which users performed tasks representative of those for whom the geosimulation was designed (Maguire 2001). The setting can be in the field or a controlled laboratory: "the aim is to gather information about the users' performance with the system, their comments as they operate it, their post-test reactions and the evaluator's observations" (Maguire 2001, p. 615). In the experimental setting, three to six subjects per session were scheduled to work as a group to use the prototype software during the discussion of competing evacuation solutions (exit placement) for school-shooting scenarios. The initial target was five group members, as this was the optimal number for group performance according to Maguire (2001). The actual number of members depended on the number of people available for each session; larger or smaller groups can still effective for decision-making. Some studies show that smaller groups tend to be more satisfied, with the individual members feeling they had more influence within the group and that the group worked more cooperatively (Golembiewski 1962; Thomas and Fink 1963). Slater (1958) determined that members of a group of size five were most satisfied. In a study by Hackman and Vidmar (1970), the researchers studied groups ranging from two to seven members tasked with three different group tasks to determine the effectiveness of the different sizes on group interaction and group products. The researchers determined that the optimal size for the comfort of the group members is four or five, but that groups achieved consensus with varying numbers of sub-groups for other tasks (Hackman and Vidmar 1970).

Each group completed two sessions to determine exit placement. In the first session each group uses the more traditional media of blueprints of the school to discuss evacuation solutions and in the second session, the group uses the geosimulation to discuss evacuation solutions. The first method of data collection was a video recording of the discussion of each group during their sessions to be analyzed after the session.

Several scholarly sources were examined for alternative media to compare to the geosimulation. The first source was a case study of crisis planning in four Massachusetts schools (Goldman 2008). Goldman (2008) found that not only are there no federal laws concerning crisis planning in schools, but even in states that do legislate crisis planning in schools, few have plans in place and they are often outdated, rarely reviewed, and rarely practiced. The four schools whose plans Goldman examined contain mainly text documents listing numbers to call, generic (instead of school-specific) responses to a number of hazardous events, blueprints, and hand-drawn maps.

A second source consisted of seven crisis management plans downloaded from school websites and an interview with a domain expert (Arkansas Safe School Initiative 2010; Chaminade College Preparatory High School 2010; Commonwealth High School 2010; Fred Fifer III Middle School 2010; Los Angeles Unified School District 2010; Minnesota Department of Public Safety 2010; Nicoles 2010; Tazewell Elementary

School 2010). The documents contain instructions to undertake lock-downs in the event of school shootings.

The second method of data collection used in this step was the satisfaction questionnaire. A post-session questionnaire was given to each of the subjects to collect information on their experience during the discussion. This questionnaire is used in conjunction with the data collected on video.

The data are analyzed using both quantitative and qualitative methods. The quantitative analysis consists of the chi-square test of homogeneity to assess how the group discussion differed between the sessions with the geosimulation and the sessions with the conventional format of information in use, blueprints. This test was chosen for two reasons: the number of subjects is small and the data are best represented in categorical format. The chi-square test is used to compare the observed distribution of results with the expected distribution of results at a 95 percent level of probability ($\alpha = .05$). Qualitative analysis of the data was also performed using thematic analysis and AST. The analysis looked at the group discussion rather than individual-level data, in order to understand how the groups used the blueprint and geosimulation to understand crisis information to decide on exit placement.

3.2 Agent-based Modeling in Second Life

The school-shooting geosimulation used in this study was based on the design of a Second Life geosimulation used to understand evacuation patterns for a fire emergency in a building and was designed by Crooks, Hudson-Smith, and Dearden (2009). In their geosimulation, Crooks, Hudson-Smith, and Dearden (2009) designed a two-story building in which agents were placed. These agents were to respond to an emergency signal and evacuate the building. The resulting movements were observed during a run of the geosimulation and movement patterns were recorded.

To create the geosimulation, Crooks, Hudson-Smith, and Dearden (2009) developed a two-story building out of the “primitives” (i.e. simple shapes) offered in Second Life, which are basic 3D geometric objects such as spheres, rings, and cubes that can be manipulated into many different shapes. Building textures are applied by mapping images onto the surfaces of the building. Primitives are also used to create furniture, stairs, and exit signs. The agents are also created using primitives – one primitive per agent with an image of a person mapped onto the surface. The behaviors of the system are created using Linden Scripting Language (LSL), which is an internal, event-driven language embedded in 3D objects. The space in which the agents move is continuous (in contrast to movement in gridded space). To move through the building to exits, the agents follow exit-signage out of the building. Each movement of the agent requires evaluation of whether the destination has been reached (is the exit at the present location), which entails either the agent leaving the building or moving toward the exit if it is not at the present location. If the agent decides to move, a direction is determined based on the signage indicating the closest exit and avoidance of obstacles (furniture, walls, and other agents). The movement of all the agents is sequential and a messaging system controls this movement sequence while special collision objects detect obstacles for the agents to avoid.

In designing the school-shooting geosimulation for this research, many of the concepts and elements were incorporated from the Crooks, Hudson-Smith, and Dearden

(2009) geosimulation in Second Life, but the implementation was accomplished without the explicit use of the scripts from the model. The first step required that “land” was rented, with U.S. currency, within Second Life to develop the model. Next a school building was developed. There is an active market of developed objects to purchase within Second Life, and a school building was available that met the needs of this research. The building had the required spaces, a corridor with classrooms, a large entrance, and a large common space to compare to the spaces in the blueprint, but was two stories. To keep the space similar in both sessions, the second story was moved to become an extension of the first story. A messaging system set up the system, started the simulation run, sent messages to the agents sequentially to move, and reset the system. To move, an agent determined the closest exit and whether he or she was located within a classroom. If the agent was within a classroom, then the goal was to barricade the door. When the first agent in the classroom reached the door, an internal message was sent for the door to lock and all the students in the room were barricaded in. If the agent was outside of the classroom, then the movement was first away from the shooter, next towards the nearest exit, and last avoiding any obstacles, such as walls and other agents, in a move to the exit. The shooter moved toward the nearest victim while avoiding walls and locked doors. A total of seventeen unique objects, each with an individual script, were used in this geosimulation, while over 100 objects with scripts were developed in total during the development phase.

The final model used by the participants was a single-story school building developed in Second Life. The building can be viewed from any angle and had no roof so that an overhead view could be used. There are a number of classrooms along a corridor, a large room, an office, and an entryway (Figure 5). The blueprint also includes these areas with a different configuration (Figure 6).

Figure 5. Geosimulation Layout.

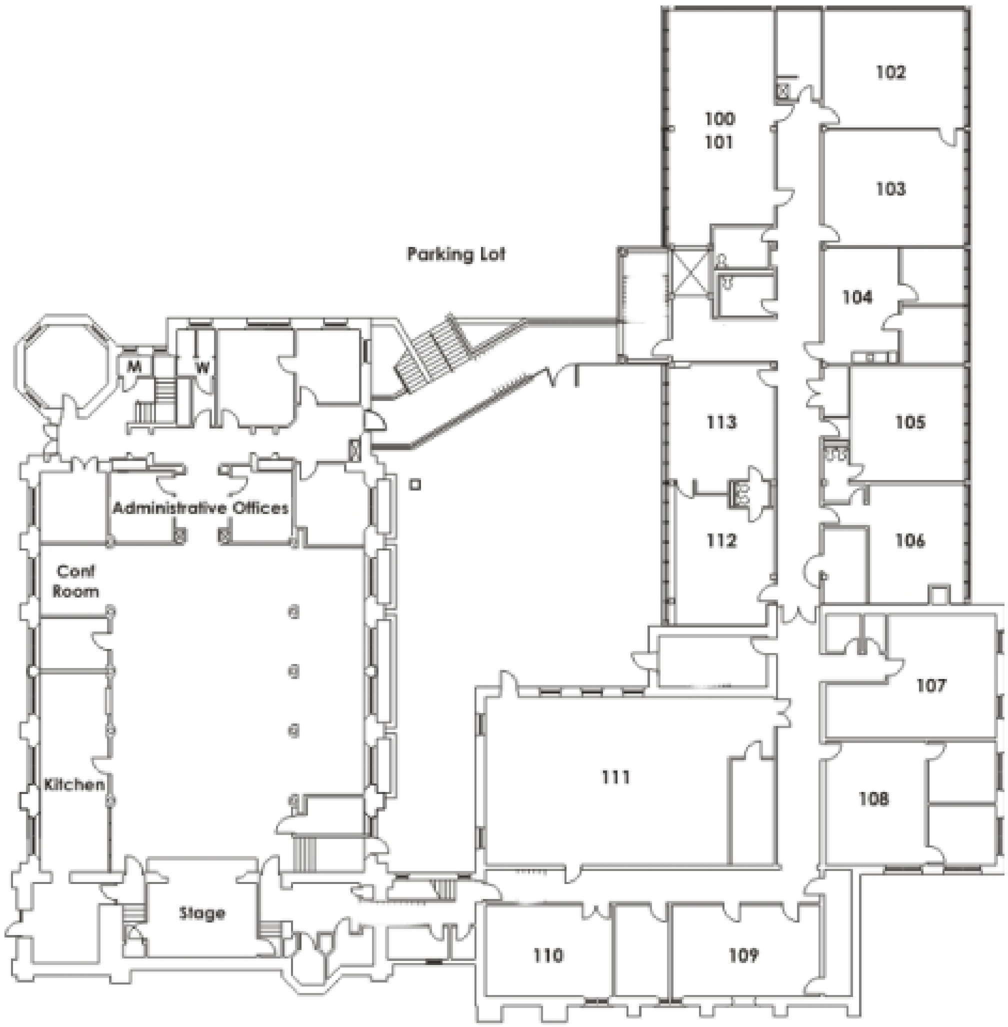

Figure 6. Blueprint Layout.

The geosimulation was accomplished by setting up a number of students in the classrooms or in the large room, determining where two additional exits would be placed along the external walls, and placing the shooter in an entranceway. The students were placed in areas with random placement and orientation to vary the activity within the room (Figure 7).

Figure 7. Agents in Geosimulation.

The geosimulation then started and the participants viewed the moving students and shooter. The agents, both victims and shooter, moved sequentially and each move corresponded to a step (Figure 8). The victims tried to exit the building or barricade themselves inside classrooms while avoiding the shooter. The shooter moved toward potential victims and shot them. When the simulation was over, the school was reset, which deleted the students and shooter and reset all the barricaded doors.

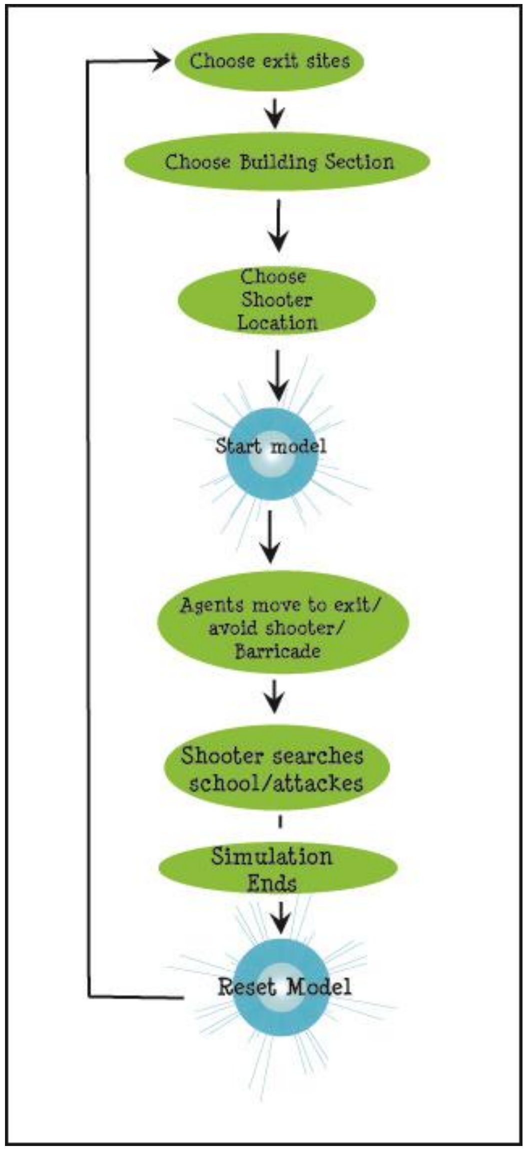

Figure 8. Geosimulation Information Flow.

The messaging system (MS) controls the order of agent movement. When the simulation starts, the MS sends out a message to move the first agent on the list. If the agent sends back a message indicating that it is still a viable agent, the MS sends back a message to move. If the agent sends a message that it is no longer viable, the MS removes the agent from the list. Non-viable agents have been shot, barricaded themselves in a room, or have exited the building. This continues until there are no more agents on the list.

The victim agent (VA) is 2 m tall, which is the average height of avatars in Second Life (Crooks, Hudson-Smith, and Dearden 2009). When the VA receives a move message, the closest exit is determined. An object is then used to determine if there are any obstacles in the path of the agent. If an obstacle exists, the VA determines if the obstacle is a door. Doors exist on the classrooms and if there is a door and the VA is inside the classroom, the VA will try to barricade the door. If the door is already locked by another VA, then the current VA determines there is an active barricade and marks itself as no longer moving. If the door is not locked but three meters away, the VA locks the door and marks itself as no longer moving; otherwise the VA takes a step towards the door and waits for another move message. If the obstacle is not a door, the VA rotates fifteen degrees for up to five times to orient to a path with no immediate obstacles, takes a step forward, and waits for the next move message. If the obstacle is the shooter, the VA rotates to the opposite direction and takes a step. If there are no obstacles, the VA takes one 1.3 meters-long step toward the exit and waits for the next move message. Ando, Ota, and Oki (1988) found that walking speed increases linearly from .35 m/second, when space is only .25 m^2/person, to 1.35 m/second when space is 1.5 m^2/person. Personal space is 4 m^2/person inside the classrooms and is greater in the hallway and gym. While this indicates the agents should move faster, there are obstacles such as desks and bleachers that reduce the space available for moving. In addition, the area around the shooter becomes unused space. The students are also moving obstacles and impede one another (Nicoles 2010). The speed of 1.3 m/second reflects the size of a fast walking step for the agents based on the amount of space available and the presence of obstacles. This is the average speed of the pedestrian agents found in Crooks, Hudson-Smith, and Dearden's (2009) model of agents leaving a building during a fire. If the VA moves through an exit, it marks itself as no longer moving. This information is summed in Figure 9.

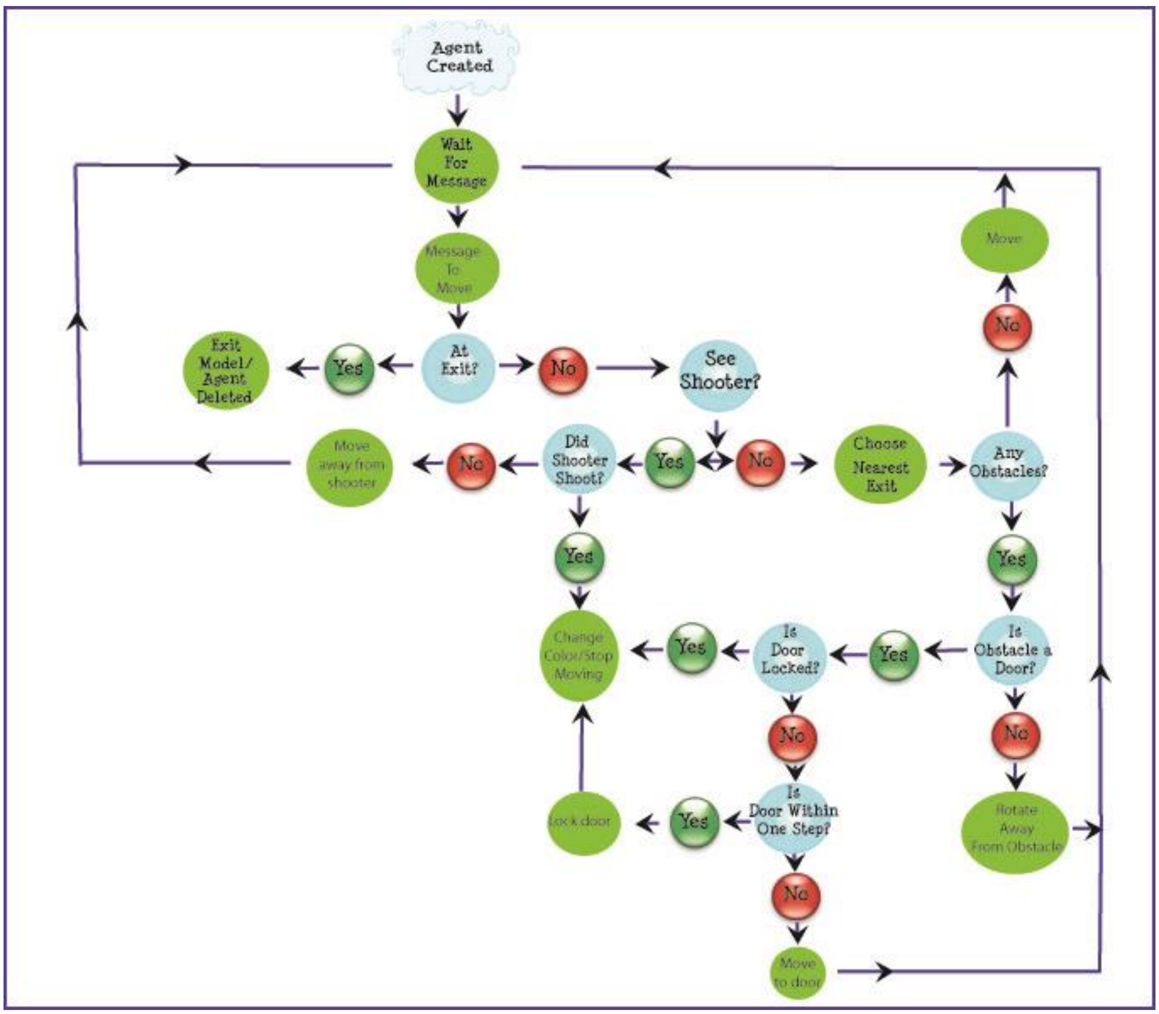

Figure 9. Victim Agent Information Flow.

When the shooter agent (SA) receives a move message, the closest VA is determined. The SA checks the path in the same manner as the VA, with the exception that the SA does not lock doors but avoids locked doors and chooses another target (Figure 10). When a VA is within a few meters of the SA, the SA shoots the VA. The VA then marks itself as no longer moving. At the end of the simulation, the reset object deletes the agents and unlocks all the doors. This information is summed in Figure 10.

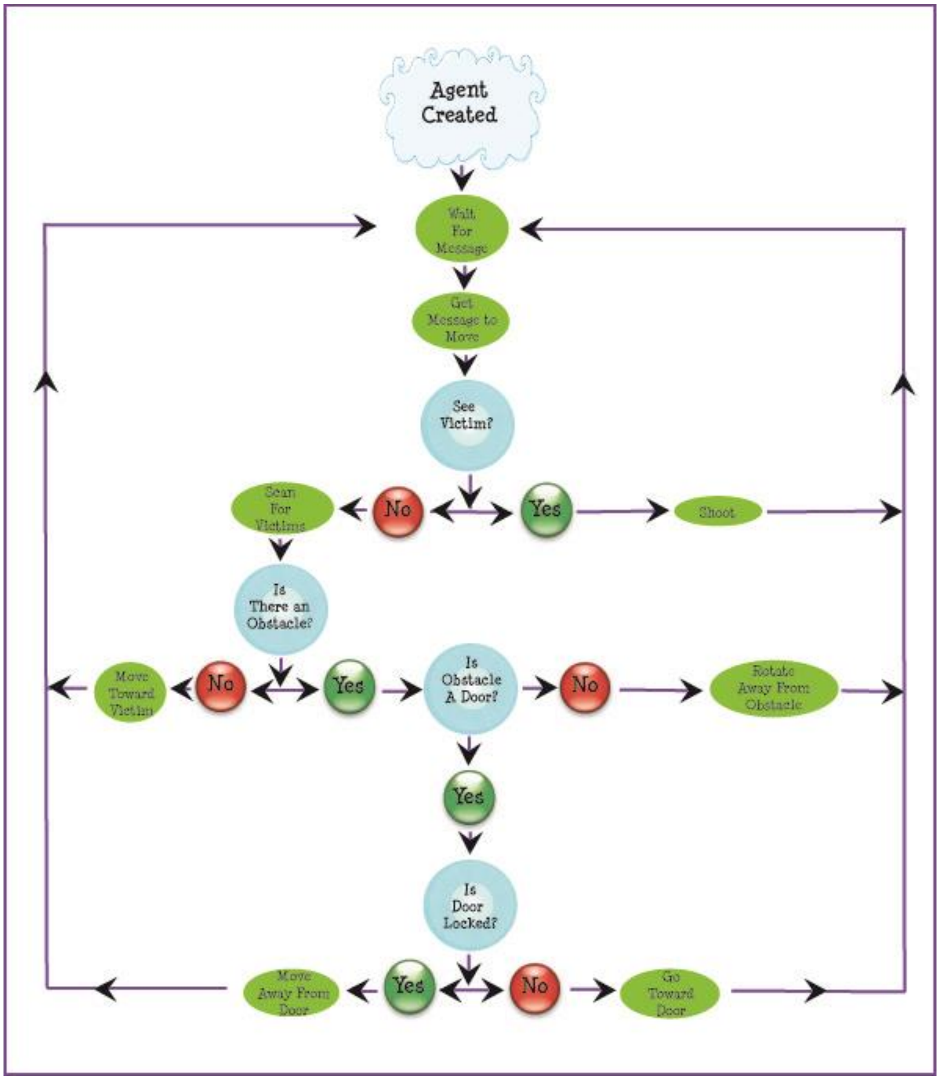

Figure 10. Shooter Agent Information Flow.

The model verification was achieved through iterative development. Each component was tested separately to determine that each piece functioned as expected.

The testing consisted of coded statements that were displayed when certain events took place. When these statements were displayed at the correct event, the component was incorporated into the bigger program and then tested again to determine whether the interaction with the other pieces continued as expected. One issue that became apparent was a problem with the messaging system. When the number of agents still alive and moving became small, the messaging system cycled through the list of agents faster than the agents could finish their programs and wait for the next message. This means that at some point in the program, the messaging system sends out a message to an agent and waits for a reply. The agent is not in listening mode so misses the message and the simulation effectively ends. The fix is to slow the time between messages, but the wait time can only be so long, as the movement of agents becomes so slow that subjects no longer understand that the model is working. At the best waiting period for messaging speed and simulation speed, the model still stops, but runs, on average, approximately four minutes. All the programmed behavior, such as students avoiding the shooter, exiting the school, and barricading themselves in, as well as the shooter searching for victims and shooting them, are displayed in the simulation run as recognized by the initial test group. This problem results from a limitation of the software and might require using a different program, such as Repast or Netlogo, for agent-based modeling. Unfortunately, the graphics of other agent-based modeling software are insufficient for this study. Another option, at this time, is to work with the Second Life developer, Linden Labs, to create built-in functionality that allows control of agents in ways similar to other agent-based software.

Validation of the model was determined through use by a test group. The purpose of the model was to incorporate the three structures, animation, interactivity, and agent-based modeling, into a geosimulation that was recognized as a shooting event within a school by a group discussing the event for decision-making purposes. With minimal direction, the test group easily recognized the animated building as a school and understood the interactivity of moving exits and the shooter as well as reorienting their perspectives of the school. The group recognized the agent-based modeling component as the event of the shooting but did determine that the agents should reflect a more accurate image of students. The victims are formed in the shape of a block and have an image of a person on the front surface as done by Crooks, Hudson-Smith, and Dearden (2009) in their simulation in Second Life (Figure 11).

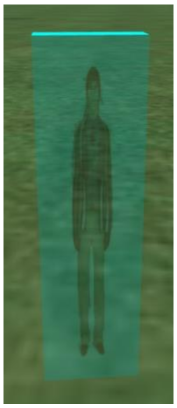

Figure 11. Agent Design.

The Crooks, Hudson-Smith, and Dearden (2009) model is used by experts to determine traffic flow through a building, while this current model is used by inexperienced users, and these users expressed the need for more naturally visualized agents. This would be an avenue for future models but was not done here due to the complexity of the coding and the little advantage for more accurate results within the context of this study, which requires only a prototype.

3.3 Participants

The questionnaire contains a section regarding the participants' experience with blueprints, geosimulations, Second Life, and emergency situations. The groups ranged in size from three to six people; one group had three, five groups had four and one group had six members. The participants ranged in age from 26 to 63 (Table 2) and had varying profession backgrounds (e.g., biologist, police officer, nurse, and lobbyist) (Table 3).

Table 2. Sex and Age Distributions of Participants

Age Group					Sex	
20-29	30-39	40-49	50-59	60-69	Male	Female
2	9	9	2	3	13	12

Table 3. Professions of Participants

Profession	Number
Administration	2
Child Rearing	1
Contractor	1
Education	1
Finances	1
Food Prep	1
Information Sciences/ Computers	3
Law Enforcement	3
Lobbyist	1
Natural Sciences	4
Nursing	2
Student	5

Nineteen of the twenty-five participants had some background in group decision-making, fourteen of these had had extensive training in this area, and six had no experience. Eleven of the twenty-five participants had some background in emergency planning, six of these had extensive training, and fourteen had no training in this area. None of the participants had any prior experience with Second Life (Table 4).

Table 4. Background Experience of Participants

	Experience Level		
	None	Some	Extensive
Second Life	25	0	0
Group Decision-making	7	6	12
Emergency Planning	16	4	5

While seven groups participated in the study, only six were included in the analysis. The initial group was a test group to determine whether there were any problems with the geosimulation. Each group’s dialogue was analyzed independently of the others to determine the unique interaction with the technology present in the dialogue.

3.4 Analysis Methods

3.4.1 Dialogue

To understand how the participants used the methods of the technology to generate ideas for exit placement during the group discussion, the information in the dialogue was broken into manageable sections called topics. Breaking dialogue into segments based on topics is an approach used to create more manageable information and to parse out important information. This approach requires a researcher to understand the contexts of discussions to determine what constitutes a topic (Boufaden, Lapalme, and Bengio 2001; Purver 2011). For the dialogue in these sessions, two types of topics emerged. One type of topic reflected the participants’ attempts to understand the technology presented to them and is designated as an “understanding” topic. The second type of topic occurred when participants discussed solutions to the task at hand, such as where to place two additional exits in a school in the case of a school shooting, and is referred to as an “idea” topic. By breaking the information into topics, the researcher can develop smaller sections of information to analyze.

The second step in the analysis process is to associate appropriation moves (Table 1) with the dialogue. The following two sections show the dialogue broken into topics for smaller data segments and the association of appropriation moves with the structures within each technology.

Each technology presented to the participants has one or more structures that are available to the users as relevant information concerning the presented task. The structures of the geosimulation, as discussed previously, are animation, interactivity and agent-based modeling, which present the layout of the school and the movement of students and shooter through the school. The blueprint is a symbolic drawing that summarizes the complex information in structures and is intended to have one meaning (Boland and Collopy 2004; Goetsch, Chalk, and Nelson 2000). In this study, the blueprint is a two-dimensional drawing, showing two of the three dimensions of a school building, and the relevant structure is the symbol set that depicts the building's information.

***3.4.1.1 Understanding Topics*.** In understanding topics, the group is orienting itself to the use of the technology. The following is an example of a group examining the blueprint and determining the layout of the school. The types of appropriation moves associated with the discussion are explained in the following section of dialogue.

> R: "So this is a little confusing; not sure if that's storage or a way out."
> DH: "That looks like a wall to me."
> R: "Oh yeah."
> S: "Internal stairs?"

One type of appropriation move in this discussion is direct – explicit (1a). In this type of move, the structure is mentioned directly, such as R indicating that the blueprint symbolic structure represents a storage area or a way to move out of the area. Another example of this move is DH stating that the symbolic structure represents a wall. This type of move indicates an active use of the structure in the discussion. This particular appropriation move can be in conjunction with other moves as explained below.

A second type of appropriation move used here is constraint – definition (6a). In this move, the structure is defined to have a particular meaning, constraining the use of the structure during the discussion. An example of this move is DH stating that the particular symbol is a wall.

A third type of appropriation move in this discussion is affirmation – agreement (7a), where the participant agrees with how the structure is used. In this exchange, R responds to DH by agreeing with the use of the symbol as a wall. Agreement brings the group closer to consensus on how to use the structure while potentially rejecting any other use of the structure.

The fourth type of appropriation move in this discussion is constraint – query (6e), where the participant is asking for a particular meaning of the structure. There are two examples of this type of appropriation in the dialogue above. The first is R questioning whether a particular symbol is a storage area or a way to move out of the area and including the group in determining this. The second example is S asking whether a symbol represents internal stairs. This type of move opens the possible appropriation of the structure up to discussion by the group.

In the geosimulation, three structures comprise the technology and can potentially be appropriated by the groups in order to understand the technology and develop solutions, as shown in the following three statements from separate exchanges.

DH: “OK, I’m sorry. So where are the exits now?”

S: “OK, so those are classrooms?”

D: “Something over by the hallways, that part somewhere.”

In the first two examples, the participants are using a direct – explicit (1a) appropriation move of the animation structure by mentioning the exits and classrooms. The participants are also using a constraint – query (6e) appropriation move to determine what part of the animation represents the exit and the classrooms. In the third example, the participant is directly appropriating the interactive structure by determining where to place the exit within the technology.

During the simulation run, the third structure, agent-based modeling, is appropriated in the following two examples from separate exchanges.

D: "Did we see any of the doors get barricaded?"

S: "OK, so they're gravitating towards the exit?"

In the first example, the door changes color if the students in the classroom barricade it. The participant uses a constraint – query (6e) move to inquire whether the doors had in fact changed colors and were barricaded. The second example is another constraint – query (6e) move to determine the movement of the students as well as a direct – explicit (1a) appropriation move in referencing the agent-based structure.

3.4.1.2 Idea Topics. In the idea topics, the groups discuss how to move people through a particular area of the school to an area of a potential exit. The following example is of an idea topic in which the participants are discussing the flow of people out of particular areas.

> DH: "But, it's just, do you want the people who are way over here to have to come all this way?"
> R: "No, it would, uh, it would have to go …"
> DH: "They can go up, right?"
> R: "That way, or this way right out to here. Right out there."
> DH: "Interesting."
> S: "Look, if some of these are shooting people, they're going to be in the most centralized location, probably."

This discussion uses a direct-explicit (1a) appropriation of the structure of the blueprint multiple times when explaining different possible locations of the shooter instead of using alternative information such as previous experience in a school to support statements.

3.4.1.3 Themes. Each topic is then analyzed for any ideas that emerge using thematic analysis. The themes addressed here are based on use of the technology to determine a creative solution to the task. Two criteria are relevant to determining an appropriate theme. The first is that an idea involves new information to help place exits. If a participant suggests leaving everything as is and just lets whoever makes it out be the survivors, then no new information is presented to help in new exit placement. This is not considered a relevant idea.

The second criterion is that the theme reflects the use of the methods of the technology. An example of this is the theme that window structures can be used as an alternative to the doors as exits. Neither the blueprint nor the geosimulation technology presents windows as a form of exit, yet windows are discussed across multiple groups as a potential escape route as an alternative to an exit. By breaking down the dialogue into themes, appropriation moves could be associated with specific themes expressed by the group. Appropriation of the structures of the technology reflects the use of the structures during the discussion of the group.

Analysis across groups is done by comparing the number and types of relevant themes containing appropriation moves for the methods in the technologies. This comparison elucidates how well the groups are using the information presented to understand the problem and create solutions for exit placement. This information is then compared across technologies.

3.4.2 Participant Questionnaire

The questionnaire consists of fourteen yes/no questions, with space after each question in which individuals can describe why they chose yes or no. These questions are based on AST literature, as discussed in the literature review, and reflect the attitudes of the participants towards the technology. Questions 1, 2, and 3 ask the subjects to express their view on the effectiveness of the methods used in the technology during the group discussion (DeSanctis and Poole 1994). Questions 4, 5, and 6 inquire as to how the subjects feel the animation and interactivity components of the technology contributed to their understanding of the information presented to them (DeSanctis and Poole 1994). Questions 7 and 8 give the subjects an opportunity to express their views on the uncertainty of the solution choices in the information presented to them (DeSanctis and Poole 1994). Questions 9, 10 and 11ask the participants whether their overall experience with the technology was positive or negative (Chin, Gopal, and Salisbury 1997; DeSanctis and Poole 1994). Questions 12, 13 and 14 ask about previous experience with Second Life, group decision-making and emergency situations/emergency planning.

The first eleven questionnaire responses in the form of yes/no answers were used to perform a chi-square test of homogeneity to determine the acceptance of the technologies and their structures by the participants and how the perception of the participants addressed the research questions. The non-parametric test is chosen for the following reasons: the data are best represented in a categorical format, the sample size is small, and the data do not have a normal distribution. The chi-square test compares the observed distribution of results with the expected distribution of results at a 95% level of probability ($\alpha = .05$).

The written responses are analyzed for each technology to determine likes and dislikes using themes. The themes are narrowed to those explicitly discussing the structures of the technology. These results are compared across technologies to determine whether each technology would be used voluntarily by groups that are presented with it.

3.5 Data Collection Procedure

Seven data sessions were conducted, with seven different groups. The initial group served as a test group to correct any problems that might arise with the technology or instructions. The next three sessions were held in a conference room at Texas State University – San Marcos. The fourth session was held in a closed lunch room at Palm Beach County Environmental Resource Management facility. The fifth and sixth sessions were held in the homes of one of the participants from each group. Each group had two discussion sessions, a blueprint session, and a geosimulation session. The team members were informed before they participated that the discussions of each session would be videotaped and each was required to fill out a waiver prior to beginning their first session. The blueprint session was presented first and the geosimulation session was presented second.

During the blueprint session, the participants were presented with a generic school blueprint and two pieces of paper to mark any potential exits during discussion. The video recording was started and the participants were informed that they were asked, as a group, to place two additional exits on the blueprint. The placement was based on the hypothesis that the proposed school had only money for two exits in the case of a school shooting and the exits had to be place on the external walls. The participants had no time limit on their discussion and were not to involve the researcher in any of their deliberation. At the end of the discussion, the participants filled out a questionnaire.

The geosimulation session had the same instructions as the blueprint session. A projector, connected to a laptop, projected a scene from Second Life of a generic school building onto a screen. The group was instructed to discuss the exit placement within this projection. In this scenario, the researcher was also a non-participant except in facilitation of the movement of the exits for the group. One computer was available and Second Life contained a learning curve, so the researcher acted as the interface with Second Life for the group. No questions were allowed to be asked of the researcher for guidance or informational purposes. At the end of the session, the participants filled out a second questionnaire with the same questions for the geosimulation.

3.6 Summary

In this research, subjects are asked to determine effective evacuation solutions to the crisis situation of a school shooting. The group is asked to place a limited number of exits at different places within the building to optimize evacuation.

The Second Life virtual environment is used in this research to provide each subject in the group unlimited visual perspectives of the school-shooting scenario. Users can control exit and shooter locations as well as their visual perspective within the geosimulation. Second Life’s animation and interactivity is used to test the ability of the users to explore and analyze the information of the school-shooting scenario. The agent-based model of the geosimulation in Second Life is tested to determine its effectiveness in improving the interactions using the basic elements of the system and to assess any resulting emergent behavior. The blueprint session provides for baseline against which the effectiveness of the geosimulation can be judged.

The solution options had no pre-calculated probability distribution associated with the failure or success of evacuation based on exit placements. As there is no measurable quantity available to compare the different choices, the level of uncertainty associated with the solution choices, not the risk, is examined in the results. The methods of animation, interactivity and agent-based modeling are used to design the geosimulation in this study. The geosimulation is tested to determine how effective these methods are in aiding groups' understanding of the uncertainty associated with different choices. These methods are compared to the format of information currently used in school crisis plans, blueprints.

CHAPTER 4.

ANALYSIS AND RESULTS

4.1 Thematic Analysis and Appropriation Moves

The dialogue of each group is divided into two types of topics, idea topics and understanding topics, to develop smaller segments for analysis. Each group devoted more time understanding the use of the geosimulation technology than in understanding how to use the blueprint. Each group also devoted more time developing ideas to place exits during their geosimulation session than their blueprint session. The most time any group spent understanding the blueprint technology (240 minutes total spent discussing the technology by group III) is shorter than the least time any group devoted to understanding the geosimulation technology (521 minutes total spent discussing the technology by group V). The exception to the understanding time is Group VI, which spent no time developing understanding of either technology. Looking at the groups as a whole, four of the groups devoted much more time to generating ideas with the geosimulation technology than the blueprint technology (Groups I, II, IV and VI) (Table 5).

Table 5. Understanding and Idea Generation Times (seconds)

	Blueprint		Geosimulation	
	Total time of understanding topics	Total time of idea topics	Total Time of understanding topics	Total time of idea topics
Group I	208	496	1064	2027
Group II	85	606	424	1806
Group III	240	102	899	468
Group IV	171	519	779	1193
Group V	190	145	521	177
Group VI	0	50	0	1569

The dialogue contains numerous discussions on where to place the exits so that any potential victims could escape from a shooter within the school. Patterns indicating unique ideas generated during discussion to help decide on exit placement are designated as themes and are extracted from the discussions to determine the distribution and commonality of the different themes within the groups. The number of unique themes found across all dialogues is thirteen (Table 6), and the participants discuss both the technology and prior experience when developing these thirteen themes. The relevant themes were determined to be only those with appropriation moves that directly referenced the technology and contained information indicating idea generation within the group for solution development. There were six relevant themes found in the dialogues and these themes are discussed in the following sections.

Table 6. Unique Themes in Dialogue

Theme
Extended definition of exits
Mathematical method of exit placement
Shooter placement changes outcome
Exit placement does not guarantee safety of students
Use of windows as exit points
Time of day changes scenario
The grade level of school changes placement of exits
Hiding as alternative to exiting the building
Use exits to move people between rooms
Other emergency scenarios important to exit placement
Compare number of dead for all simulations to determine best exit placement

4.1.1 Types of Exit

In this theme, the participants discuss the aspects of different types of exits, such as an exit-only style of door or an exit/entrance style. This theme is discussed by three groups across the blueprint and geosimulation sessions.

During the blueprint session of Group I, the participants discuss what type of exit would be most effective, by focusing on whether the exit should also allow entrance to the school. The following is the exchange from this session:

> D: “I think one of the reasons I think that they probably placed exits in schools, if this is going to be a school for example, you know one of the things is to be able to let people out but another is not to let people in.”
> DH: “Hmmm.”
> D: “I don’t know if we have any direction, necessarily on what kinds of exits these are. I don’t know if that makes a difference in where you choose to put them in?”
> DH: “That’s a good point.”
> S: “Right, I mean if you put one down here, you wouldn’t have it open. Or, people didn’t, you wouldn’t want kids in and out all day.”
> R: “Yeah, they do say it’s an exit, not an entrance, so maybe we can just assume that it’s only an out since it doesn’t say entrance.”

The participants reference the symbolic structure of the blueprint multiple times to designate the area of discussion and whether that would be an appropriate area for an exit-only type of door. This interchange includes participants questioning the placement of exits with reference to the blueprint symbolic structure and reaching a consensus about the type of exit and location within the blueprint. This particular discussion leads to the placement of an exit. While the information concerning the type of exit is not explicitly contained in the blueprint, use of the technology results in examining this information as a group. This idea emerges as a theme due to the development of additional information that could aid the group in understanding how people move through the school during crises, in order to place the exits more effectively.

During Group IV’s geosimulation session, the participants discuss the use of exits as an escape option and as an entrance for authority figures, such as police or emergency workers. Like Group I, this discussion focuses on the type of exit available, but look at the doors not only as exits but also as entrance options for outsiders to enable the rescue of students. The animated structure is referenced during the discussion to show where the placement of the exits should be and how the students would be affected. This discussion did not lead to an immediate placement of an exit but is kept as part of the criteria of placement.

Group V also discusses the type of exit they would use in their geosimulation session. This discussion focuses on how a door that would allow entrance to outsiders could also let in the shooter. The group wants to keep the shooter from having multiple entrances, a possibility that is discovered during the simulation run. The group references the animation during the discussion, questioning the meaning of the animated exits and defining the exits as structures representing a locked exit and agreeing on the definition. This leads to an exit placement.

4.1.2 Using Math to Determine Exit Placement

A second theme focuses on how using math, such as determining the midpoint of an area, can aid in placing exits. Two groups express this theme across both types of sessions.

The following example shows Group I during its blueprint session discussing this theme:

> R: "Well, you have this exit, this … yeah, I don't know, you could highlight it all and do a distance, a weighted distance and get the centroid of each room and figure out how far it takes to get to each exit and figure out which exit supports …"
> S: "How many, how many students can fit in each room."
> R: "Right, exactly. Yeah."

In this discussion, the participants discuss finding a central point between the classrooms in order to give all students the most opportunity to exit the building with the group agreeing to this approach. The group references the symbolic structures of the blueprint directly when discussing this option, showing where the middle point would exist. In this discussion, the participants discuss using given information in a way not presented by the technology to create new information for decision-making. The discussion affects the placement of an exit latter in the discussion.

During Group I's geosimulation session, math is again suggested. Referencing the animation structure directly, the group discusses putting the exit in the middle of the classrooms in two separate discussions, which leads to an agreement on the use of this method by the members and the placement of an exit.

In the geosimulation session for Group II, participants discuss minimizing the distance for all students by choosing the middle place between classrooms. During the discussion, the animation structure is referenced by pointing to the area of the middle instead of verbally describing the point. The interactive structure is referenced when participants discuss moving the current door, based on the discussion of minimization, or leaving it where it is, leading to the placement of an exit.

4.1.3 Time of Day Changes Exit Location Effectiveness

The third theme that is extracted from the dialogue focused on the effect that the time of day has on the utility of the exit placement. Three groups discuss this theme across the two types of sessions. The discussion indicates that an exit in the gym would have a different effectiveness during games, which have a different density of population in a particular space than regular school hours.

In Group I's blueprint session, the participants discussed how the students would be distributed differently during lunch or during class periods. This would have an effect on the utility of exit placement, as a door in the lunch area would be less effective during class time. The symbolic structure of the blueprint is directly referenced during the discussion but no exit placement is decided.

During Group IV's geosimulation session, the participants discuss the use of the gym at different times of the day. The gym could be used during school hours or after school hours for a game. This leads to the determination that the gym would have more individuals after hours than during school hours and therefore a door in the gym would have varying effectiveness. The animation structure is referenced directly and a decision for exit placement is reached.

Group V's geosimulation session includes a discussion of this theme. The following section shows this discussion.

> M: "No you didn't say what, was this during the school hours or was this …"
> V: "Students."
> M: "… or was this like after school, you know they have like a game or whatever it is they play basketball or something."
> P: "If you want to control …"
> M: "No if the shooter is like P said, let's say after school they have a game in the gymnasium, whatever they play, basketball …"
> V: "Or volleyball."
> M: "… and there will be a high volume of people over there, that's one scenario. But that's after school, but this is during school, a different scenario."

The group discusses how the placement of a door in a particular area would only lead to utility as an escape for a few hours a day when there is a large concentration of students in the lunch area. The group eventually agrees that there would be more use of an exit if it were placed near the classrooms. The animation structure is referenced for this discussion and a decision of exit placement is made.

4.1.4 Windows as Alternative Exits

The fourth theme that emerges is the use of existing windows as alternative exits. Development of this theme results from discussion by the groups of using windows as exits to free up the two future exits to areas with no alternative escape options. All six groups discuss this theme, with a few groups discussing this theme across both types of sessions.

In Group II's blueprint session, the participants discuss using windows as a form of emergency exit, allowing the limited number of exits to be placed in other areas. The group decides that windows could be difficult to open and therefore choose not to use them in the decision process. The symbolic structure of the blueprint is referenced during the discussion while there is a question concerning the meaning of a symbol. All agreed that the symbol depicts a window and continued to determine the placement of an exit.

One participant in Group IV's blueprint session mentions using windows as alternative exits but the group does not continue with this theme or use it to determine exit placement. In this comment, the symbolic structure of the blueprint is referenced.

In Group I's geosimulation session, the discussion includes using windows as a method of escape and using the doors to fill in the gaps where no windows are available. This exchange is from Group I's geovisualization session.

> R: "Right, that's what I said, that's why if we are going to assume they can go out windows …"
> DH: "That they can go out those windows."
> R: "That there's enough windows in the other and the rest is open enough with a permanent exit that they have a window or door, a front door option that they're gonna have over in the classrooms and the same thing in the administrative office."

The group references the animation when pointing to the placement of windows and the interactive structure when moving the doors to new locations. The group agrees on the use of windows as alternative exits and uses this information later in the discussion to determine door placement.

Groups II, III, IV, V and VI discuss the windows as alternative exits in the geosimulation sessions. Group II agrees that though the windows are large enough for exits, they could be difficult to get through. The animation structure is referenced directly but no decision is made to place an exit based on this discussion. Group III agrees during the geovisualization session that the windows can be broken and used as exits. The animation and interactive structures are referenced during the discussion and a decision to place an exit is made. Group IV briefly discusses the windows as an exit option in two topics during the geovisualization session but no decision is made to place an exit. The animation component is referenced. Group V discusses using windows as an alternative to exits in two topics during the geovisualization session. The animation structure is referenced and the structure also elicits a question to determine what the animation represents. The group decides on exit placement. Group VI discusses the windows as alternative exits from the building. They reference the animation and interactive structures but do not use this information in determining where to place the exit.

4.1.5 Shooter Placement Changes Utility of Exit/Varying Exit Utility

A fifth theme involves the particular placement of the shooter as an important variable in understanding the school-shooting system, while a sixth theme involves the varying utility of exit placement. These two themes are found in all of the geosimulation sessions but in none of the blueprint sessions. These themes are tied together in the discussions of the groups. These themes did not lead directly to a decision to place an exit, but changed the perspective of the groups in determining how an exit could be effective.

The following excerpt is from Group I's geosimulation session discussing the themes:

> DH: "I agree. I can't think of a better way, but my concern is that putting it in there means someone can stand here and shoot straight down the hallway. And get, get everybody. I don't know how to solve that problem, but …"
> R: "Well, if they don't, you can just go room by room and get everybody."

In this discussion, the participants note that if the shooter is standing at a different point, then the utility of the particular exit placement would change. Group I decides that no matter where the doors were placed, a change in the location of the shooter could make the doors less effective. This exchange also reveals frustration with the idea that no matter where the doors are placed, some students could be shot. Within this discussion, the animation, interactive, and agent-based structures are all referenced and agreed upon.

Group II participants stated that no matter where the exits are, the students nearest the gunman could be shot. One participant noted that the model did not provide the numbers of students that would have died in each scenario for comparison, while a second participant responded that the blueprint scenario also did not provide that information or any modeling information. The entire group agreed with this assessment. All three structures, animation, interactive, and agent-based, are referenced.

Group III discussed how the shooter might be able to get the students directly next to him, regardless of where the exits are placed, and sometimes could block exits, as shown in the following example:

E: “He’s at the main exit.”
M: “Yeah, that kinda defeats our thought process on that one.”
E: “So, there’s not much you can do about it: the exit is in the right place, it’s just that if the kids don’t know what’s going on …”
M: “And if there’s some kids right there, there’s only one place for them to get out.”
E: “Yes. So it’s not the door, it’s just where the gunman is.”

In this discussion, every location chosen by participants results in some risk to the potential victims, regardless of where the exit is placed. This indicates an understanding that no correct place exists to evacuate all students, but that each placement creates risks that potential victims would need to consider. In this example, the previous theme, that changing the location of the shooter changes utility of exit placement, is included.

Groups IV, V and VI discussed, in multiple topics, that the door placement does not matter and that the shooter will always control one of the exits. All agree and reference all three structures during the exchange.

The themes and appropriation moves for the blueprint sessions for all groups are summed in Table 7. The themes and appropriation moves for the geosimulation sessions for all groups are summed in Table 8.

Table 7. Blueprint Sessions: Themes and Appropriation Moves

Theme	Group	Appropriation Moves
Extended definition of exits	1	1a,6e,7a
Mathematical method of exit placement	1	1a,7a
	0	0
Shooter placement changes outcome	0	0
Exit placement does not guarantee safety of students	0	0
Use of windows as exit points	2	1a,6e,7a
	4	1a
Time of day changes scenario	1	1a

Table 8. Geosimulation Sessions: Themes and Appropriation Moves

Theme	Groups	Appropriation moves Animated Structure	Appropriation moves Interactive Structure	Appropriation moves Agent Based Structure
Extended definition of exits	4	1a	0	1a
	5	1a	0	0
Mathematical method of exit placement	1	1a	1a,7a	1a
	2	1a	1a	0
Shooter placement changes outcome	1	1a,7a	1a,7a	1a,7a
	2	1a	1a	1a
	3	1a	1a	1a
	4	1a	0	1a
	5	1a	0	0
	P	1a	1a	0
Exit placement does not guarantee safety of students	1	1a	0	1a,7a
	2	1a	1a	0
	3	1a	1a	1a
	4	1a	0	0
	5	1a	1a	1a
	P	1a	1a	1a
Use of windows as exit points	1	1a	0	1a
	2	1a,7a	0	0
	3	1a,7a	1a	0
	4	1a,7a	0	0
	5	1a,6a,6e	0	0
	P	1a	1a	1a
Time of day changes scenario	4	1a	0	0
	5	1a,7a	0	0

4.2 Attitudes

The questionnaire was developed to gauge the perception of the usefulness of the technologies used in the task sessions. Two sections of the questionnaire are examined to determine the participants' perceptions. The first section consists of yes/no questions and is evaluated using a chi-square test of homogeneity to determine if there is a strong difference in the opinions of the participants concerning the two different technologies. The second section consists of answers describing the reasoning behind the yes/no answers and this information is examined by breaking the answers into themes of likes and dislikes. This approach explores in more detail the subtle differences concerning the participants' perceptions of the usefulness of the two technologies.

4.2.1 Questionnaires: Yes/No Responses

In performing the chi-square test of homogeneity on the yes/no answers of the questionnaire, only two results show a significant difference and result in the rejection of the null hypothesis. The null hypothesis is that the yes/no answers regarding the blueprint session and the geosimulation session are the same for each question. If true, one can conclude that there is no difference between the two technologies concerning their effects on the participants. The alternative hypothesis states there is a statistically significant difference in the yes/no answers for each question between the two sessions indicating that the technologies have different effects on the participants. Question 1 and Question 6 had significantly larger number of yes answers for the geosimulation technology than the blueprint technology.

Question 1 asked whether participants feel the technology can offer flexibility in understanding solutions to the problem. This result is a statistically significant preference (α=.5, χ^2=6.64) by the participants for use of the geosimulation for understanding the solutions they develop for the problem presented to them. Question 2 asked if the technology promotes group discussion of individual ideas. Statistically, there appears to be no significant difference between the technologies (α=.5, χ^2=0.00). Question 3 asked whether the technology allows for solution exploration. Again, there is no significant difference in responses to the two technologies (α=.5, χ^2=3.19). Question 4 asked the participants if the presentation of the information using each the technology is easily recognizable. No significant difference between the technologies is revealed by their answers (α=.5, χ^2=1.05). Question 5 asked if the visual presentation of the information helps them understand solutions. Again, there is no significant difference in the answers for the two technologies (α=.5, χ^2=0.22). Question 6 asked the participants if the ability to interact with the scenario promoted understanding of the solutions to the problem. There was a statistically significant difference between blueprints and the geosimulation (α=.5, χ^2=4.5). This result reflects an apparent preference among the participants for the ability to interact with the geosimulation in order to understand the implications of solutions developed. Question 7 asked the participants if the technology can represent the uncertainty of solutions and results in no significant difference between technologies (α=.5, χ^2=2.12). Question 8 asks the participants if the technology can represent the benefits and problems of solutions; no significant difference is apparent between technologies (α=.5, χ^2=0.37). Question 9 asked if the technology is appropriate for the application and responses revealed no significant difference between the technologies

(α=.5, χ^2=2.88). Question 10 asked if the technology enhances the effectiveness of group decision-making. No significant difference exists between the technologies (α=.5, χ^2=0.76). Question 11 asked the participants if they would use this technology in other group decision-making settings, and their responses indicated that there is no significant difference between the technologies (α=.5, χ^2=2.91). These results are summed in Table 9.

Table 9. Chi Square Test of Homogeneity Results

Question	1	2	3	4	5	6	7	8	9	10	11
χ^2	6.64	0	3.19	1.05	0.22	4.5	2.12	0.37	2.88	0.76	2.91

4.2.2 Questionnaires: Written Responses

The written responses are analyzed using themes to determine likes and dislikes of each technology. The themes were narrowed to those which appropriate the structures of the technology directly. These results were then compared across technologies to determine whether the technologies would be used voluntarily by groups to whom they are presented. Unlike the yes/no portion of the questionnaire, only 15 participants answered the written portion of the questions for both technologies.

There are more positive thematic comments than negative thematic comments for both the blueprint and the geosimulation. When answering the questionnaire, twenty-four positive comments concerning the symbolic structure of the blueprint are found while the structures of the geosimulation elicited forty-three positive comments.

Positive comments from the blueprint questionnaire answers, such as “visual helps understanding” and “helpful to visualize setup” show that the users found the symbolic structure helpful as a visual aid for discussing the task presented to the group. Also, comments such as “visual helps with multiple ideas” and “visual helps consider options” show the group using this structure to understand different ideas.

From the geosimulation questionnaire answers, comments such as “visual of structure easier to understand” and “3-D graphics made discussion better” reflect a feeling of easily understood animation structure. In addition, comments such as “helps to visualize ideas and outcomes” and “visuals shows both problems with ideas and the benefits of solutions” indicate that participants use the animation structure to understand the information presented for solutions. The participants comment positively about the interactive structure, for example, “can easily adjust solutions based on previous outcomes” and “moving doors and moving shooter help decide exit placement.” These statements indicate that the participants have a positive view of the ability to change components within the technology for idea generation and exploration. Also positive comments such as “multiple scenarios can be executed to compare results” and “seeing movement and outcomes of students in simulation helps understanding” indicate that the participants saw the agent-based structure as beneficial to understanding the ideas for solutions to the presented task. A few positive comments concerning the ability of the geosimulation to illuminate the uncertainty of solution choices are made. The comments “helps to understand problem domain” and “good for understanding unexpected issues” indicate the feeling that the technology can help create a more comprehensive understanding of the issues and unknown factors of a problem and potential solutions.

There are fewer comments indicating a negative view of both technologies, with fourteen negative comments for the blueprint and five negative comments for the geosimulation. The negative comments concerning the symbolic structure of the blueprint focus primarily on the lack of additional information. Comments such as “only one perspective available,” “exploration limited to user’s imagination” and “limited to group’s understanding and creativity” indicate that the participants feel they need additional information when using the blueprint. Some users indicated they have trouble understanding the symbols, which could be solved with some training or information prior to using the blueprint.

The negative comments concerning the geosimulation regard two areas. The first area is the visual depiction of the students, which do not look enough like students. The visual expression of the students could be modified to depict students more accurately in future iterations. The second area regards human nature and the ability to predict the behavior of individuals in a model. This sentiment, which also came up in two group discussions, is a source of frustration for some participants.

All of the comments related to the technology were grouped together based on content. These results are summed in Table 10.

Table 10. Questionnaire:Likes and Dislikes

	Likes			Dislikes		
Question Number	Themes	Blueprint	Geovisualization	Themes	Blueprint	Geovisualization
1	Provided overview/ visual helps understanding	2	0	Only one perspective available	1	0
	Accomodates multiple viewers	2	0			
	Exploration of ideas possible	0	3			
	Visual of structure easier to understand	0	2			
	Moving doors and moving shooter help decide exit placement	0	1			
2	Vagueness helps create solutions	1	0			
	Visual aid helps with multiple ideas	2	0			
	Allows exploration of various ideas	0	4			
	Helps to visualize ideas and outcomes	0	3			
3	Visual helped consider options	3	0	Exploration limited to users imagination	2	0
	Multiple scenarios can be executed to compare results	0	4			
4	Graphics easy to understand	0	3	Understanding symbols difficult at times	4	0
				Graphics depicting students not clear	0	3
5	Visual aid helps to discuss problem	4	0			
	3-D graphics help with task	0	2			
	Seeing movement and outcome of students in simulation helps understanding	0	2			
6	Helps to understand problem domain	0	2	No interaction available, decision based on logical assessment with personal bias	1	0
	Can easily adjust solutions based on previous outcomes	0	1			
	Movement helps to understand where to place doors	0	1			
7	Left more questions	0	2	Up to user's imagination	1	0
	Helps to understand issues not considered in blueprint such as shooter and student behavior	0	3	Hard to predict human nature	0	2
8	Visual shows both problems with ideas and the benefits of solutions	0	2	Limited to group's understanding and creativity	1	0
9				More information needed to make decision	3	0
10	Helpful to visualize setup	2	0	Not enough information to give decision-makers good direction	1	0
	Good starting point	1	0			
	Simulation allows ideas to be explored by bringing up unexpected information from various solution options	0	4			
	3-D graphics made discussion better	0	1			
11	Better than nothing	3	0			
	Would use if other tools were used in conjunction	4	0			
	Good for brainstorming	0	1			
	Good for seeing outcomes and adjusting solutions	0	1			
	Good for understanding unexpected issues	0	1			

CHAPTER 5.

SUMMARY AND CONCLUSIONS

The blueprint and the geosimulation are used effectively and positively by the decision-making groups to discuss exit placement in a school-shooting scenario. The blueprint is effectively used in the exit-placement task, but the users found that it is most useful as a visual reference for them to gain an initial understanding of the building. The blueprint is a limited aid for the generation of ideas for solutions. The users indicated that the blueprint should be used in conjunction with other tools for effective decision-making. The geosimulation is viewed as more comprehensive for depicting and understanding the problem domain. The users developed more solutions to the problem presented to them using the geosimulation. The users also felt that the uncertainty involved in the system and the solution options make confidence in decisions an issue, but use this uncertainty to prompt discussion of system assumptions.

5.1 Summary

The overall experience of the subjects met the goals of the geosimulation. The goal of the geosimulation was to present small groups with three structures: animation, interactivity, and agent-based modeling to aid in understanding a problem domain and developing solutions more effectively than the symbolic structure of the blueprint. Initial analysis of data found that more time was spent by each group (with the exception of Group VI) in developing an understanding of the geosimulation than of the blueprint, but that each group spent more time in its geosimulation session discussing solution options than in its blueprint session.

Finding themes is a method of extracting relevant information from qualitative data (Boyatzis 1998; Strauss and Corbin 1990). All of the important themes consisted of information constructed from the structures of the technologies to express new information that aids in solution exploration. The number of themes that involve direct appropriation of the technology is greater in the geosimulation sessions than in the blueprint sessions. Four themes were developed in the blueprint session with Group I discussing three of the themes and Groups II and IV discussing a fourth theme. Six themes were developed during the geovisualization sessions. All six groups developed themes, with two groups discussing three themes, two groups discussing four themes, and two groups discussing five themes.

The animation is the most referenced of the three geosimulation structures. This is in part a result of the nature of the presentation, as the interactive and agent-based structures are expressed through animation. The participants use the animation to understand the context of the geosimulation structure in agreement with Sando, Tory, and Irani (2009) and use the animation in conjunction with the interactive structure to change the visual arrangement of information to understand different solution options. The combined use of interactivity and animation is postulated by Slocum et al. (2001) as potentially giving users the ability to explore and understand information in a more effective way than animation alone. This is supported by the development of only two themes where no interactivity is used, while four themes are developed using interactivity. The two themes in which interactivity is not used concern the type of exit and how the time of day changes the utility of the exit. Both of these contain information that does not require rearrangement of the spatial elements to understand options.

The agent-based structure is appropriated in five of the six themes. De Smith, Goodchild, and Longley (2007) proposed that the interactions of individual entities in a system create properties not coupled to the properties of the system's parts. This is supported by the discussion among the groups in which agents' behavior elicited changing opinions about exit placement. Behavior not conceived of prior to the run, such as a student not exiting through a door if the route to the door required the student to head toward the shooter, are included in determining effective exit placement.

The agent-based structure has an effect on understanding the uncertainty of the solution options. In decision-making processes, choosing options requires understanding the choices available and the benefits and uncertainties inherent in them (Andrienko et al. 2007). From the dialogue, the subjects exhibited a greater understanding of the benefits and uncertainty of the options in the geosimulation sessions than in the blueprint sessions. Visual and interactive interfaces aid in the understanding process (Andrienko et al. 2007). Interactivity allows the users to test different configurations of the agent-based structure while the animation allows the users to view the space-time processes within the simulation, such as found in the study by Groff (2007). In the two themes where uncertainty is the primary discussion point, the agent-based structure is mentioned by four of the groups, the interactive structure is mentioned by four groups, and the animation structure is mentioned by all six groups.

Understanding the user's experience is a good indicator of whether the technology will be adopted and used by groups according to DeSanctis and Poole (1994). A look at the chi-square test of homogeneity analysis of the yes/no questionnaire answers indicates that groups thought the geosimulation offered more flexibility for understanding solutions and the interactive structure promoted understanding solutions more than the blueprint. A look at the answers to the written questionnaire shows an overall positive perception of the users for both the blueprint and the geosimulation. The geosimulation received approximately twice as many positive comments as the blueprint. In the positive comments, all three structures of the geosimulation are referenced multiple times, showing a positive experience with each structure. The negative comments are fewer, with the geosimulation receiving less than half of the negative comments received for the blueprint. The negative comments concerning the blueprint mainly focus on the lack of information needed to make an informed decision. The subjects indicate that the blueprint should be part of a larger toolset for this type of task. The negative comments for the geosimulation questioned the ability to predict human behavior accurately with models and the poor graphics of the agents. In addition, Thompson (2002) stated that if the processes within a system could be better understood, the uncertainty of solution options would be minimized. This is not supported by the groups' attitude toward the geosimulation, as the users felt more uncertain concerning their choices than in the blueprint sessions. While these comments are in the negative category, the overall effect is that the participants are looking at assumptions made with regards to the problem domain. During the blueprint session, no participants questioned any of the assumptions made when discussing solutions for the task. Questioning the assumptions leads to a deeper understanding of the problem domain in many discussions.

5.2 Conclusions

5.2.1 Benefits and Limitations of Technologies

While examining the dialogues of all the groups, the time spent understanding the technology was determined to be longer for all but one of the groups during their geovisualization sessions; the last group spent no time understanding either technology. In all the groups, more time was spent discussing solution ideas during the geosimulation session than the blueprint session. Additionally, every group spent more time discussing ideas in the geosimulation sessions and, with one exception, spent more time learning to understand the environment of the geosimulation sessions. None of the participants had previous exposure to Second Life. The longer time spent understanding the geosimulation compared to the blueprint could reflect the process of familiarization that new technology often requires. This may be the case each time the geosimulation is used, as the targeted groups are not expert groups but stakeholder groups whose expertise may vary depending on the issue in question. Such groups may require a period of familiarization for each task. The increased time discussing idea solutions during the geosimulation sessions in all groups indicates that more data exploration and knowledge construction took place. This is in agreement with Duke's (1989) communication-simulation model that determined that the simulation should contain a symbol set and multiple conventions that would support simultaneous discourse among multiple users. This is consistent with the findings of Roschelle and Teasley (1995) that a physics simulation creates a common language that aids the subjects in collaboration, data exploration, and knowledge construction for the problem domain.

Boyatzis (1998) states that finding themes in qualitative data is a method of finding patterns. To find the important patterns, the researcher must also be familiar with the subject matter to understand how the information relates to the subject and must give meaning to the information in the form of themes (Boyatzis 1998; Strauss and Corbin 1990). In this study, the geosimulation is designed to elicit idea generation in group decision-making by presenting the information of a school-shooting scenario through the structures of animation, interactivity, and agent-based modeling comprising a geosimulation. This information is compared to the same information presented through the symbolic structure of a blueprint, which is one of the traditional tools used in school evacuation planning. The important components within the data are the ideas generated to aid in placing exits for evacuation that also reference the structures of the technology. Any relevant themes reflect this information.

The blueprint sessions resulted in three groups developing themes that advance the information of the technology past the design of the tool while referencing the structure directly during theme development. Group I discussed all three themes and used the information to determine an exit location. Group II discussed one of the themes and, based on this discussion, determined where an exit should be placed. In Group IV, one participant mentioned windows as exit alternatives and referenced the symbolic structure directly, but the discussion was not continued by the rest of the group and the statement was not used to determine exit locations.

During the geosimulation sessions, six themes were developed by the six groups. Groups III and VI discussed three of the themes, Groups I and II discussed four themes, and Groups IV and V discussed five themes. Three of the themes were found in the geosimulation sessions of all six groups. One of these themes, the use of windows as alternative exits, also arose in the blueprint session of two groups, but only one used this information to discuss solution options. All the groups discussed this theme while appropriating the animation structure in each discussion, with three of the groups determining exit location based on the information. This is consistent with the principle that a goal of animation is to support understanding of an object's structure (Sando, Tory and Irani 2009) and it is also in agreement with the findings that a rotatable, 3D display is more effective in a spatial task than static 2D/3D displays. In the geosimulation, the windows are large and prominent as structures viewable from any angle, while the blueprint contains small, flat line symbols representing windows. The windows in the blueprint are overlooked by most of the groups, while the windows in the geosimulation are clearly a dominant feature of the buildings and were discussed by all six groups.

One theme found in the geosimulation sessions of Groups I and II is the use of a mathematical process to determine exit placement. Both groups moved exits around the structure during the discussion, referencing the animation and interactivity to determine where the distance is minimized for all the students. The combined use of animation and interactivity to discuss hypotheses is supported by Ogao (2006) in which users preferred interactive maps and developed more hypotheses using them than static maps.

Two themes are found in the discussions of Groups IV and V, with one of these themes mentioned by Group I in the blueprint session. The first theme, which refers to the design of the exits, was brought up by the two groups to determine if each exit should serve as an exit-only type of door or as an exit and entrance, such as the front entrance of the school. Group IV decided that the exit-and-entrance option allows rescuers to enter and would positively impact the event, while Group V decided that an exit-and-entrance option would provide the shooter with too many entrance points and would negatively impact the event. The animation structure was referenced by both and the agent-based structure was referenced by one group. Again, the animation and interactivity structures support the exploration of hypotheses (Ogao 2006). The agent-based structure is mentioned in determining that the shooter can use different points of entrance, which reflects the use of agent-based modeling to understand the processes and the uncertainty of the system better (Benenson and Torrens 2004; Epstein 2002; Gilbert and Terna 2000; Thompson 2002). Both groups used this information to determine the location of an exit.

The second theme found in the geosimulation session of Groups IV and V is the changing utility of the exit with time of day. Both groups discussed how the number of students in large areas, such as a gym or lunch area, changes throughout the day and how an exit in those spaces would be very effective for only a few hours a day. Animation is the only structure referenced by either group. Both groups use the information to determine the placement of an exit. The appropriation of animation for the themes in Groups IV and V again supports Sando, Tory, and Irani (2009)'s findings that 3D structures aid in spatial tasks more effectively than 2D/3D static displays such as a blueprint.

5.2.2 Uncertainty

The two themes of shooter placement as an important variable and the varying utility of exit placement were found in all the geosimulation sessions but in none of the blueprint sessions. These two themes were sometimes discussed separately but often in the same discussion. When discussed together, all three geosimulation structures were referenced. None of the groups used these themes to determine exit placement directly, but rather to understand the problem domain further. These two themes consisted of the idea that the utility of exits for escape purposes by the students changes based on elements other than exit placement and that an important component of the problem is the changing placement of the shooter. This information did not come up in the blueprint sessions. The development of these themes occurred only after the first run of the geosimulation. After seeing the movement of the students and shooter, participants noticed that the movement had a more unpredictable pattern than thought from the blueprint. Comments such as “I guess what I’m confused at is, no matter what, the kids have to cross the line of fire to get out” and “What about the kids in the hall? They’re gonna get barricaded in the hall. If you’re not in a room, the kids in the hallway are essentially trapped without doors” expressed an understanding of behavior not discussed in the blueprint sessions. The agent-based structure displayed properties that emerge from the interaction of the components that are not part of the coding of each component. These properties aid in informing participants of behaviors of the system not previously understood. This reflects the statement made by Katehi, Pearson, and Feder’s (2009) that a system is more than the sum of its parts and system understanding requires understanding of the parts and their interactions. This also supports the studies that show simulations are effective in elucidating emergent properties, with computer simulations being the most effective (Colella 2000; Katehi, Pearson, and Feder 2009; Penner 2001; Resnick 1996; Resnick and Wilensky 1998; Wilensky and Reisman 2006; Wilensky and Resnick 1999). Understanding of these emergent properties also leads to awareness that there is a component of uncertainty in this situation that cannot be controlled and that risk is involved with each placement. Andrienko et al. (2007) indicate the importance of understanding not just the benefits of options, but also the uncertainty inherent in the options for decision-making.

The animation and interactive structures are also referenced in these themes. The placement of shooter and location of students within the building to aid understanding of this information is consistent with Ogao (2006) in that more understanding is acquired by the use of animated and interactive maps than use of static or passively animated maps.

5.2.3 Use by Groups

According to some studies, the use of advanced technologies frequently differs from the use intended by the designers (Kiesler 1986; Markus and Robey 1988; Siegel et al. 1986). DeSanctis and Poole (1994) state that systems are adapted by the people using them based on the user needs and that they can resist them or fail to use them at all. Understanding the perception of the users towards the technology is key to predicting if the technology will be incorporated by the groups. The questionnaire answers provide a view into the users' perception of the usefulness of the technology in the assigned task. These answers are examined using the chi-square test of homogeneity and themes of like and dislike as shown in the following discussion.

In the chi-square test of homogeneity, two of the questions reflect a statistically positive view of two aspects of the geosimulation. The geosimulation is determined to be more flexible in understanding the solutions and the interactive structure is determined to be a positive part of understanding the solutions.

Overall there are more positive than negative comments from the written answers of questionnaires for both technologies. The blueprint comments indicated that the groups found the technology helpful as a visual aid but would want additional tools to make a truly informed decision. The geosimulation comments indicated a positive view of all three structures. The agent-based structure received positive comments such as “Seeing movement and outcome of students in simulation helps understanding” and “Simulation allows ideas to be explored by bringing up unexpected information from various solution options,” indicating that the subjects feel understanding the movement of the agents helps them understand the problem domain.

Thompson (2002) supports the idea that understanding the processes of systems, not just statistical outcomes, can minimize the uncertainty in solution options. The negative comments for the agent-based structure indicate a questioning of assumptions within the model and the realization that the simulation does not present an easily apparent answer. This is expressed in statements such as “I’m not seeing how that’s going to help us make the decision. We’re still making the decisions pretty much the same way. What seems like the best choice?” These comments do not support Thompson’s (2002) statement. This does not necessarily reflect the notion that understanding the uncertainty does not aid in decision-making, but rather that the participants seem to have expectations of easily identified right or wrong selection choices. The expectations of the participants could be addressed by changing the goal of the task from using the geosimulation as a means of determining the two alternative exit locations problem to domain exploration. This also indicates that the geosimulation would not necessarily be the only tool for decision-making, but would be part of a set of tools. While a few participants felt frustrated by not knowing what the assumptions of the model were, this frustration led to a discussion of the assumptions of the problem domain, a discussion which did not take place in the blueprint sessions. Exploring the problem domain is a goal of the geosimulation.

A few comments reflect issues with the graphics in both technologies. One participant stated that “Understanding symbols [is] difficult at times,” while another observed that the “Graphics depicting students [are] not clear.” These two problems are viewed as technical issues that can be resolved in future iterations of the technology. Labels can be added to the blueprint and the agents can be developed to reflect a more natural looking person.

Overall, users had a positive experience with both technologies. In the capacity that they are presented, these results indicate the participants would integrate the blueprint and the geosimulation into a group decision-making process.

5.3 Overview

While both technologies show a more positive than negative view from the user groups, all groups found the geosimulation to reflect a more comprehensive view of the problem domain, as well as a more complete view of the system. The participants also spent more time discussing ideas for solutions using the geosimulation, while developing a greater number of themes using the structures of the geosimulation than the structure of the blueprint.

5.4 Future Research

The research presented here develops a proof-of-concept geosimulation to understand the effects of the structures of animation, interactivity, and agent-based modeling on group decision-making. The geosimulation represents a school-shooting system with minimal amounts of information to understand the use of these structures for understanding the system. While the geosimulation shows a positive effect on idea generation for decision-making, more-developed systems need to be examined.

One complaint of the users is that the agents representing the people of the school are not easily identified. While this can be potentially distracting on initial use, the question of usefulness in developing a more natural agent is of interest. This type of agent would require significant financial resources and may not advance the ability of the users to explore the system and generate ideas. Future research should look at the effect of a more naturalized agent on this ability.

While running the geosimulation session, the researcher is required to be an interface for the users with the technology. Another future research avenue is to test the usefulness of developing an interface for multiple users to eliminate the expert user as the interface. Are the added resources to develop non-expert interfaces for individual exploration balanced by increased information exploration, knowledge construction, and idea generation?

This research looks at the ability of a geosimulation to generate solution ideas within a group. While this research shows that subjects using the geosimulation generate more ideas than using the blueprint in a group setting, understanding the quality of the interaction and ideas was beyond the scope of this research. Future researchers could examine the quality of interaction of the group members across these differences as well as the quality of the ideas generated to better evaluate the benefits and limitations of the geosimulation. Potential variation in group membership such as prior relationships between group members or age, sex or cultural differences could change the effect of the geosimulation on decision-making and idea quality.

This study looks at a simplified school-shooting scenario. Recent events show that there is a polarizing debate concerning school-shooting scenarios evolving in our culture. A future research direction could consider the specific solutions presented by the different groups in this debate. A geosimulation developed for the ideas held by these groups could be tested with people that are vested stakeholders to understand the application in a real world setting. In addition, the geosimulation could be tested to determine the usefulness for decision-making with regards to other crisis situations, such as a fire evacuation or hurricane mitigation to better understand the range of applicability of the geosimulation. This research could be extended to test other types of simulations, such as participatory simulations or physical model simulations, to determine the comparative benefits and limitations with the geosimulations.

APPENDIX A: QUESTIONNAIRE

Questionnaire

Age____

Profession________________________

Field of study/expertise_____________________________

Male/female__________

Subject number____

Date______

Session Number______

Time Started session________

Time Finished session_________

Questionnaire

Each question has two parts. First, answer yes or no to each question. Second, on the attached sheets, explain why you felt that yes or no was the best answer to the question. Include any information you feel is relevant in describing this.

1. The technology can offer flexibility in understanding solutions to the problem.
2. The technology allows for presentation of individual ideas to the group for discussion.

3. The technology allows for exploration of solutions to the problem.
4. The technology presents the information in an easily recognizable manner.
5. The visual presentation of the information helps in understanding the solutions to the problem.
6. The ability to interact with the scenario helps in understanding the solutions to the problem.
7. The technology can represent the uncertainty involved in any solution to the problem.
8. The technology can represent the problems and benefits of each solution to the problem.
9. I am satisfied with the technology for this application.
10. Using this technology enhances the effectiveness of group decision-making.
11. If I had the opportunity to use this technology in other group decision-making settings, I would.
12. What is your experience using Second Life?
13. What is your experience with group decision-making?
14. What is your experience with emergency situations/emergency planning?

APPENDIX B: CONSENT FORM

Communication in Group Decision-Making Study Consent Form

You are being asked to take part in a research study of how agent-based models aid in communication for groups making decisions.

This study is being conducted by Shelrie Houlton, doctoral student in the Department of Geography at Texas State University – San Marcos. This research is a part of the dissertation to be written to fulfill the doctoral program.

What the study is about: The purpose of this study is to learn how using an agent-based model of a school shooting scenario will aid in group decision-making. The results will be compared to the use of maps and images for groups making the same decisions.

You have been chosen: You have been asked to participate because you signed up for the research in a voluntary sign-up sheet asking graduate students to participate in the research.

What we will ask you to do: If you agree to be in this study, you will participate in two sessions. Each session will take one hour and will require you to work in a group of five subjects to discuss exit solutions for school shooting scenarios. One of the sessions will provide maps and images, while the other session will provide an agent-based model within a computer environment. The discussion among the groups will be videotaped and there will be a questionnaire to fill out at the end of each session.

Risks and benefits:

The physical risk involves sitting at a desk and discussing information with other participants, sometimes with the use of a computer. The information in the school shooting scenario is not of a graphic nature, but if at any point you are uncomfortable, you can leave the session.

If you feel the experience of the study is uncomfortable and need to talk to someone concerning the experience, you can contact counselors at the following centers:

1. Texas State University Health Center (free to registered Texas State students): http://www.counseling.txstate.edu/resources/shoverview/mental.html
2. Theravive Counseling (San Marcos): http://www.theravive.com/cities/tx/counseling-san-marcos.aspx
3. Apa Center (Austin): http://www.apacenter.com/

The benefits of participating in the study are in learning to work better with other members of a group in discussing options for group decision-making.

Compensation: There is no compensation for these sessions.

Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public, we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records. The videotapes of the sessions will be erased after the sessions have been transcribed and analyzed, which is estimated to take six months.

Taking part is voluntary: Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. If you decide not to take part or to skip some of the questions, it will not affect your current or future relationship with Texas State University. If you decide to take part, you are free to withdraw at any time.

If you have questions: The researcher conducting this study is **Shelrie Houlton**. Please ask any questions you have now. If you have questions later, you may contact Shelrie Houlton at sh28518@txstate.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact **the IRB chair, Dr. Jon Lasser (512-245-3413 – lasser@txstate.edu), or Ms. Becky Northcut, Compliance Specialist (512-245-2102).**

Copy of findings: If you require a summary of findings, contact Shelrie Houlton at sh28518@txstate.edu and she will provide a copy to you when they are available.

You will be given a copy of this form to keep for your records.

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature ___________________________________ Date ______________________

Your Name (printed)
____

In addition to agreeing to participate, I also consent to having the discussion sessions taped and to answering written questions.

Your Signature ___________________________________ Date ______________________

Signature of person obtaining consent __________________________ Date ____________

Printed name of person obtaining consent _________________________ Date __________

This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the IRB on [date], IRB approval number [number].

BIBLIOGRAPHY

Ando, K., H. Ota, and T. Oki. 1988. "Forecasting the Flow of People." *Railway Research Review* 45:8-14.

Andrienko, G., N. Andrienko, P. Jankowski, D. Keim, M.-J. Kraak, A. MacEachren, and S. Wrobel. 2007. "Geovisual Analytics for Spatial Decision Support: Setting the Research Agenda." *Special issue of the International Journal of Geographical Information Science* 21:839-57.

Ariane, B. 2011. "3D Virtual World." http://arianeb.com/more3Dworlds.htm (accessed November 2, 2011).

Arias, E., H. Eden, G. Fischer, A. Gorman, and E. Scharff. 2000. "Transcending the Individual Human Mind – Creating Shared Understanding through Collaborative Design." *ACM Transactions on Computer-Human Interaction* 7:84-113.

Arias, E., and G. Fischer. 2000. "Boundary Objects: Their Role in Articulating the Task at Hand and Making Information Relevant to It." In *International ICSC Symposium on Interactive & Collaborative Computing (ICC'2000)*, 567-575. Wetaskiwin, Canada.

Arkansas Safe School Initiative. 2010. "Crisis Intervention Plan." http://www.arsafeschools.com/SamplePlans.htm (accessed December 3, 2010).

Aronson, J. 1992. "The Interface of Family Therapy and a Juvenile Arbitration and Mediation Program." PhD diss., Nova University, Fort Lauderdale, FL.

———. 1994. "A Pragmatic View of Thematic Analysis." *The Qualitative Report* 2 (1): 1-3.

Baseline. "Glossary of Terms used in Usability Engineering." http://www.ucc.ie/hfrg/baseline/glossary.html (accessed October 20, 2010).

Battleson, Brenda, Austin Booth, and Jane Weintrop. 2001. "Usability Testing of an Academic Library Web Site: A Case Study." *Journal of Academic Librarianship* 27:188-98.

Becciani, Ugo, Vincenzo Antonuccio-Delogu, Alessandro Costa, and Catia Petta. 2012. "Cosmological Simulations and Data Explorations: A Test Case on the Usage of Grid Infrastructure." *Journal of Grid Computing* 10:265-77.

Bell, B. Sue, Richard Hoskins, Linda Pickle and Daniel Wartenberg. 2006. "Current practices in spatial analysis of cancer data: mapping health statistics to inform policymakers and the public." *International Journal of Health Geographies*. 5(1):49.

Benenson, I., and P. M. Torrens. 2004. *Geosimulation: Automata-Based Modeling of Urban Phenomena*. London: John Wiley & Sons.

Blundell, D. 1997. "Collaborative Presentation Technologies: Meetings, Presentations, and Collaboration." In *Groupware: Collaborative Strategies for Corporate LANs and Intranets*, edited by D. Coleman, 269-320. Upper Saddle River, NJ: Prentice Hall.

Boland, Richard, and Fred Collopy. 2004. "Managing Matters for Management." In *Managing as Design*, edited by Richard Boland and Fred Collopy, 3-18. Stanford, CA: Stanford University Press.

Boufaden, Narjes, Guy Lapalme, and Yoshua Bengio. 2001. "Topic segmentation: A first stage to dialog-based information extraction." In *Proceedings of the 6th Natural Language Processing Pacific Rim Symposium, NLPRS '01*, 273-280. Tokyo: Japan.

Boyatzis, R. E. 1998. *Transforming Qualitative Information: Thematic Analysis and Code Development.* Thousand Oaks, CA; Sage.

Bradsher-Frederick, Howard R. 1981. "Gaming-Simulation: A Mode of Communication for Conveying Systematic Research." *Journal of Experiential Learning and Simulation* 3:271-92.

Brashers, Dale E., Mark Adkins, and Renee A. Meyers. 1994. "Argumentation and Computer-Mediated Group Decision-Making." In *Group Communication in Context*, edited by Lawrence R. Frey, 263-82. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cairns, R., B. Cairns, H. Neckerman, S. Gest, and J. L. Gariepy. 1988. "Social Networks and Aggressive Behavior: Peer Support or Peer Rejection?" *Developmental Psychology* 24:815-23.

Carrara, A., M. Carrdinali, R. Detti, F. Guzzetti, V. Pasqui, and P. Reichenback. 1991. "GIS Techniques and Statistical Models in Evaluating Landslide Hazard." *Earth Surface Processes and Landforms* 16:427-45.

Chaminade College Preparatory High School. 2010. “Crisis Response Plan.” http://www.chaminade.org/westhils/hs/FinalCrisisResponsePlan.pdf (accessed December 3, 2010).

Chen, Teresa. 2002. “Design Considerations for Computer-Based Simulations in Education.” *World Conference on Educational Multimedia, Hypermedia and Telecommunications* 2002:293-94.

Chi, M. T. H. 2005. “Commonsense Conceptions of Emergent Processes: Why Some Misconceptions are Robust.” *Journal of the Learning Sciences* 14:161-99.

Chi, M. T. H., and R. D. Roscoe. 2002. “The Processes and Challenges of Conceptual Change.” In *Reconsidering Conceptual Change: Issues in Theory and Practice*, edited by M. Limon and L. Mason, 3-27. AA Dordrecht: Netherlands: Kluwer Academic Publishers.

Chin, Wynne W., Abhijit Gopal, and W. David Salisbury. 1997. “Advancing the Theory of Adaptive Structuration: The Development of a Scale to Measure Faithfulness of Appropriation.” *Information Systems Research* 8:342-67.

Colella, V. 2000. “Participatory Simulations: Building Collaborative Understanding through Immersive Dynamic Modeling.” *Journal of the Learning Sciences* 9:471-500.

Coleman, D. 1995. “Groupware Technology and Applications: An Overview of Groupware.” In *Groupware: Technology and Applications*, edited by D. Coleman and R. Khanna, 3-41. Upper Saddle River, NJ: Prentice Hall.

“Columbine High School.” 2010. *The New York Times*, April 18. http://topics.nytimes.com/top/reference/timestopics/organizations/c/columbine_high_school/index.html (accessed December 2, 2010).

Commonwealth High School. 2010. “Crisis Management Plan.” http://www.pen.k12.va.us/VDOE/Instruction/model.pdf (accessed December 3, 2010).

Comptdaer, Jérôme, Emmauel Chiva, Stèphane Delornne, Henri Morlaye, and Jèrôme Volpoët. 2007. “Multi-Scale Behavioral Models for Urban Crisis Training Simulation.” Proceedings of BRIMS. http://brimsconference.org/archives/2007/papers/07-BRIMS-025.pdf (accessed March14, 2011).

Couclelis, H. 1988. “Of Mice and Men: What Rodent Populations Can Teach Us About Complex Spatial Dynamics.” *Environment and Planning A* 20 (1): 99-109.

Crabtree, Benjamin F., and William L. Miller. 1992. *Doing Qualitative Research: Research Methods for Primary Care*. Vol. 3. Thousand Oaks, CA: Sage.

Creighton, J. L., and J. W. R. Adams. 1998. *CyberMeeting: How to Link People and Technology in Your Organization*. New York: Amacom.

Crooks, Andrew, Andrew Hudson-Smith, and Joel Dearden. 2009. Agent Street: An Environment for Exploring Agent-Based Models in Second Life." *Journal of Artificial Societies and Social Simulation* 12:4-10.

Denzin, Norman K., and Yvonna S. Lincoln. 1994. *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage.

DeSanctis, Gerardine, and Marshall Scott Poole. 1994. "Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory." *Organization Science* 5:122-47.

De Smith, J., Michael F. Goodchild, and Paul A. Longley. 2007. *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques, and Software Tools*. Leicester, England: Matador.

Duke, Richard D. 1989. "Gaming/Simulation: A Gestalt Communications Form." In *Communication and Simulation: From Two Fields to One Theme*, edited by David Crookall and Danny Saunders, 33-52. Clevedon, UK: Multilingual Matters.

Dykes, Jason, Alan M. MacEachren, and Menno-Jan Kraak. 2005. "Exploring Geovisualization." In *Exploring Geovisualization*, edited by J. Dykes, A. M. MacEachren, and M.-J. Kraak, 3-19. Oxford: Elsevier.

Epstein, Joshua M. 2002. "Modeling Civil Violence: An Agent-Based Computational Approach." *Proceedings of the National Academy of Sciences* 3:243-50.

Fabrikant, S. I. 2001. "Building Task-Ontologies for Geovisualization." Paper presented at the ICA Commission on Visualization and Virtual Environments Pre-Conference Workshop on Geovisualization on the Web, July 31-August 2, in Beijing, China.

Fedra, Kurt, and Enrico Feoli. 1998. "GIS technology and spatial analysis in coastal zone management." *EEZ Technology*, 3: 171-179.

Finn, T. A., and D. R. Lane 1998. "A Conceptual Framework for Organizing Communication and Information Systems." Paper presented at the annual meeting of the International Communications Association in Jerusalem, Israel.

Fisher, B. Aubrey. 1980. *Small Group Decision-Making: Communication and the group process*. New York: New York: McGraw-Hill.

Fisher, C. B. 1993. "Integrating Science and Ethic in Research with High-Risk Children and Youth." Society For Research In Child Development. *Social Policy Report* 7:1-27.

Franklin, S., and A. Graesser. 1996. "Is it an Agent, or Just a Program? A Taxonomy for Autonomous Agents." Paper presented at the Third International Workshop on Agent Theories, Architectures, and Languages, August 12-13, in Budapest, Hungary.

Fred Fifer III Middle School. 2010. "School Crisis Response Plan." http://www.fms.cr.k12.de.us/CrisisResponsePlan10-11.doc (accessed December 3, 2010).

Frey, Lawrence R. 1999. *The Handbook of Group Communication Theory & Research*. Thousand Oaks, CA: Sage.

Gasson, Susan. 2003. "Human-Centered vs. User-Centered Approaches to Information System Design." *Journal of Information Technology Theory and Application (JITTA)* 5:29-46.

Gersh, John R., Jennifer A. McKneely, and Roger W. Remington. 2005. "Cognitive Engineering: Understanding Human Interaction with Complex Systems." *Johns Hopkins APL Technical Digest* 26:377-82.

Gilbert, N., and P. Terna. 2000. "How to Build and Use Agent-Based Models in Social Science." *Mind and Society* 1:57-72.

Goetsch, David, William S. Chalk, and John A. Nelson. 2000. "Technical Drawing." In *Delmar Technical Graphics Series* (4th ed.), 3. Albany: New York: Delmar Learning.

Goldman, Steven B. 2008. "Crisis Planning in Four Massachusetts Public School Districts: A Case Study." PhD diss., University of Massachusetts, Lowell.

Golembiewski, R. T. 1962. "Effects of Task Characteristics on Group Products." *Journal of Experimental Social Psychology* 4:162-87.

Grant, Taran, and Arnold G. Kluge. 2005. "Data Exploration in Phylogenic Inference: Scientific, Heuristic or Neither." *Cladistics* 19:379-418.

Groff, Elizabeth. 2007. "'Situating' Simulation to Model Human Spatio-Temporal Interactions: An Example Using Crime Events." *Transactions in GIS* 11:507-30.

Grudin, J., and S. E. Poltrock. 1997. "Computer-Supported Cooperative Work and Groupware." In *Advances in Computing*, edited by M. V. Zelkowitz, 269-320. San Diego, CA: Academic Press.

Guzzetti, F., A. Carrara, M. Cardinali, and P. Reichenbach. 1999. "Landslide Hazard Evaluation: A Review of Current Techniques and their Application in a Multi-Scale Study, Central Italy." *Geomorphology* 31:181-216.

Hackman, Richard, and Neil Vidmar. 1970. "Effects of Size and Task Type on Group Performance and Member Reactions." *Sociometry* 33:37-54.

Harrower, M. 2002. "Visualizing Change: Using Cartographic Animation to Explore Remotely-Sensed Data." *Cartographic Perspectives* 39:30-42.

_______. 2003. "Tips for Designing Effective Animated Maps." *Cartographic Perspectives* 44:63-65.

Hoff, R. 2006. "A Virtual World's Real Dollars." *Business Week*, March 28,13-15.

Holton, Glyn A. 2004. "Defining Risk." *Financial Analysts Journal* 60:19-25.

Hubbard, Douglass. 2007. *How to Measure Anything: Finding the Value of Intangibles in Business*. Hoboken, NJ: John Wiley & Sons.

Jankowski, Piotre. 2001. "GIS-supported collaborative decision-making: results of an experiment." *Annals of the Association of American Geographers*. 9(1):48-70.

Jankowski, Piotre, Timothy L. Nyerges, Alan Smith, T.J. Moore and Emory Horvath. 1997. "Spatial group choice: a SDSS tool for collaborative spatial decisionmaking." *International Journal of Geographic Information Science*. 11(6):577-602.

Jermann, P. 2002. "Task and Interaction Regulation in Controlling a Traffic Simulation." In *Proceedings of CSCL*, January 7-11. Boulder, CO: International Society of the Learning Sciences.

Kaplan, Stanley, and B. John Garrick. 1981. "On the Quantitative Definition of Risk." *Risk Analysis* 1:11-27.

Katehi, Linda, Greg Pearson, and Michael Feder, eds. 2009. *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*. Washington, DC: The National Academies Press.

Keim, D. A., Panse, C., and Sips, M. 2005. "Information Visualization: Scope, Techniques and Opportunities for Geovisualization." In *Exploring Geovisualization*, edited by J. Dykes, A. M. MacEachren, and M.-J. Kraak,23-52. Oxford: Elsevier.

Keys, Bernard, and Joseph Wolfe. 1990. "The Role of Management Games and Simulations in Education and Research." *Journal of Management* 16:307-36.

Kiesler, S. 1986. "The Hidden Messages in Computer Networks." *Harvard Business Review* 64(1):46-59.

Kirwan, O., W. Golden, and P. Molloy. 2007. "Energy Management Information Systems: An Exploratory Study of Implementations using Adaptive Structuration Theory." Paper presented at the ICEIS Conference, Madeira, Portugal, June 14-16.

Knight, Frank H. 1921. *Risk, Uncertainty, and Profit*. New York: Hart, Schaffner, and Marx.

Koua, Etien L., Alan MacEachren, and Menno-Jan Kraak. 2006. "Evaluating the Usability of Visualization Methods in an Exploratory Geovisualization Environment." *International Journal of Geographic Information Science* 20:425-48.

Kumar, P., C. P. Rosé, Y. C. Wang, M. Joshi, and A. Robinson. 2007. "Tutorial Dialogue as Adaptive Collaborative Learning Support." In *Artificial Intelligence in Education*, edited by R. Luckin, K.R. Koeding and J. Greer, 383-390. Amsterdam, The Netherlands: IOS Press.

Laituri, Melinda, and Kris Kodrich. 2008. "On Land Disaster Response Community: People as Sensors of High Magnitude Disasters Using Internet GIS." *Sensors* 8:3037-55.

Larson, C. E., and F. M. LaFasto. 1989. *Teamwork: What Must Go Right/What Can Go Wrong*. Newbury Park, CA: Sage.

Lauzon-Guay, Jean Sebastien, and Robert Scheibling. 2010. "Spatial Dynamics, Ecological Thresholds and Phase Shifts: Modeling Grazer Aggregation and Gap Formation in Kelp Beds." *Inter-Research Marine Ecology Progress Series* 403:29-41.

Leemkuil, H., T. de Jong, R. de Hoog, and N. Christoph. 2003. "KM Quest: A Collaborative Internet-Based Simulation Game." *Simulation & Gaming* 34:89-111.

Leininger, M. M. 1985. “Ethnography and Ethnonursing: Models and Modes of Qualitative Data Analysis.” In *Qualitative Research Methods in Nursing*, edited by M. M. Leininger, 33-72. Orlando, FL: Grune & Stratton.

Longely, P.A., and Batty, M. (Eds.). 1997. Spatial analysis: modelling in a GIS environment. New Yourk, NY: Wiley.

Los Angeles Unified School District. 2010. “Standard Emergency Procedures for Schools.” http://adultinstruction.org/administrators/handbooks/emergency.pdf (accessed December 3, 2010).

Lunetta, Vincent N., and Harold J. Peters. 1985. “Simulations in Education: Sharpening an Old Tool.” *Curriculum Review* 24:30-32.

MacEachren, Alan, and Menno-Jan Kraak. 1997. “Exploratory Cartographic Visualization: Advancing The Agenda.” *Computers and Geosciences* 23:335-43.

MacEachren, A.M., G. Cai, R. Sharma, I. Rauschert, I. Brewer, L. Bolelli, B. Shaparenko, S. Fuhrmann and H. Wang. 2005. “Enabling collaborative geoinformation access and decision-making through a natural, multimodal interface.” *International Journal of Geographic Information Science* 19(3):293-317.

Maguire, Martin. 2001. “Methods to Support Human-Centered Design.” *International Journal of Human-Computer Studies* 55:587-634.

Markowitz, Harry. 1952. “The Utility of Wealth.” *The Journal of Political Economy* 60:151-158.

Markus, M. L., and D. Robey. 1988. “Informational Technology and Organizational Change: Causal Structure in Theory and Research.” *Management Science* 15:583-98.

McGrath, J. E., and A. B. Hollingshead. 1994. *Groups Interacting with Technology*. Thousand Oaks, CA: Sage.

Midtbø, T., K. Clarke, and S. Fabrikant. 2007. “Human Interaction with Animated Maps: The Portrayal of the Passage of Time.” Paper presented at the 11th Scandinavian Research Conference on Geographic Information Science, September 5-7, in Ås, Norway.

Minnesota Department of Public Safety. 2010. “Emergency Planning and Procedures Guide for Schools.” http://www.hsem.state.mn.us/uploadedfile/schools.pdf (accessed December 3, 2010).

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. "Final Report." http://www.oilspillcommission.gov (accessed October 3, 2010).

Nicoles, Terry. Phone interview with author. Merritt Island, FL, December 7, 2010.

Nocke, Thomas, Michael Flechsig, and U. Bohm. 2007. "Visual Exploration and Evaluation of Climate-Related Simulation Data." Paper given at the IEEE Simulation Conference, Winter, Tokyo, Japan.

Ogao, P. J. 2006. "A Tool for Exploring Space-Time Patterns: An Animation User Research." *International Journal of Health Geographics* 5:35-43.

Olweus, D. 1978. *Aggressions in Schools*. Washington, DC: Hemisphere.

Ondrejka, C. 2007. "Collapsing Geography (Second Life, Innovation, and the Future of National Power)." *Innovations: Technology, Governance, Globalization* 2:27-54.

Paulus, Paul B., and Huei-Chuan Yang. 2000. "Idea Generation in Groups: A Basis for Creativity in Organizations." *Organizational Behaviour and Human Decision Processes* 82 (1):76-87.

Penner, D. E. 2001. "Complexity, Emergence, and Synthetic Models in Science Education." In *Designing for Science: Implications from Everyday, Classroom, and Professional Settings*, edited by K. Crowley, C. D. Schunn, and T. Okada, 177-208. Hillsdale, NJ: Lawrence Erlbaum Associates.

Perry, D., S. Kusel, and L. Perry. 1988. "Victims of Peer Aggression." *Developmental Psychology* 24:807-14.

Plaisant, C., A. Rose, G. Rubloff, R. Salter, and B. Shneiderman. 1999. "The Design of History Mechanisms and their Use in Collaborative Educational Simulation." In *Proceedings of the Computer Support for Collaborative Learning*, 348-359. Stanford, CA: Stanford University Press.

"Police Tactics, Training Changing." 2010. *Denver Post*, May 17. http://extras.denverpost.com/news/col0517.htm (accessed December 2, 2010).

Prior, L., F. Wood, J. Gray, R. Pill, and D. Hughes. 2002. "Making Risk Visible: The Role of Images in the Assessment of (Cancer) Genetic Risk." *Health Risk and Society* 4:241-58.

Purver, Matthew. 2011. "Topic Segmentation." In *Spoken Language Understanding: Systems for Extracting Information from Speech*, edited by Gokhan Tur and Renato De Mori, 291-317. West Sussex: UK: John Wiley & Sons.

Rauschert, Ingmar, Pyush Agrawal, Rajeev Sharma, Sven Fuhrmann, Isaac Brewer, Alan MacEachren, Hongmei Wang, and Guoray Cai. 2002. "Designing a Human-Centered, Multimodal GIS Interface to Support Emergency Management." Paper presented at the GIS conference, November 8-9, in McLean, VA.

Reiner, M., J. D. Slotta, M. T. H. Chi, and L. B. Resnick. 2000. "Naive Physics Reasoning: A Commitment to Substance-Based Conceptions." *Cognition and Instruction* 18:1-34.

Resnick, M. 1996. "Beyond the Centralized Mindset." *Journal of the Learning Sciences* 5:1-22.

Resnick, M., and U. Wilensky. 1998. "Diving into Complexity: Developing Probabilistic Decentralized Thinking Through Role-Playing Activities." *Journal of the Learning Sciences* 7:153-72.

Rinner, Claus. 2006. "Argumentation Mapping in Collabrative Spatial Decision Making." In *Collaborative Geographic Information Systems*, edited by Shivanand Balram and Suzana Dragicevic, 85-102. Idea Group Publishing: Hershey, Pa.

Robertson, G. G., S. K. Card, and J. D. Mackinlay. 1993. "Information Visualization Using 3D Interactive Animation." *Communications of the ACM* 36:56-71.

Robinson, Anthony Christian. 2008. "Design for Synthesis in Geovisualization." PhD diss., Pennsylvania State University.

Roschelle, Jeremy, and Stephanie D. Teasley. 1995. "The Construction of Shared Knowledge in Collaborative Problem Solving." In *Computer-Supported Collaborative Learning*, edited by C. E. O'Malley, 69-97. Berlin: Springer-Verlag.

Ruël, Huub. 2009. "Studying Human Resource Information Systems Implementation using Adaptive Structuration Theory: The Case of an HRIS Implementation at Dow Chemical Company." In *Handbook of Research on E-Transformation and Human Resources Management Technologies: Organizational Outcomes and Challenges*, edited by Eanya Bondarouk, Huub Ruël, Darine Guiderdoni-Jourdain, and Ewan Oiry, 171-85. LOCATION: IGI Global.

Rushton, Gerard. 2003. "Public Health, GIS and spatial analytic tools." *Annual Review of Public Health* 24(1):43-56.

Sahli, Nabil, and Bernard Moulin. 2006. "Agent-Based Geo-simulation to Support Human Planning and Spatial Cognition." *Lecture Notes in Computer Science*. 3891:115-32.

Sakoda, J. M. 1971. “The Checkerboard Model of Social Interaction.” *Journal of Mathematical Sociology* 1:119-32.

Sando, Taylor, Melanie Tory, and Pourang Irani. 2009. “Effects of Animation, User-Controlled Interactions and Multiple Static Views In Understanding 3D Structures.” In *Proceedings of the 6th Symposium on Applied Perception in Graphics and Visualization*, 69-76. Crete:Greece: ACM.

Scheerhorn, Dirk, Patricia Geist, and J. C. Bruno Teboul. 1994. “Beyond Decision-Making in Decision-Making Groups: Implications for the Study of Group Communication.” In *Group Communication in Context*, edited by Lawrence R. Frey, 247-62. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schell, John W., and Rhonda S. Black. 1997. “Situated Learning: An Inductive Case Study of a Collaborative Learning Experience.” *Journal of Industrial Teacher Education* 34:5-28.

Schelling, T. C. 1971. “Dynamic Models of Segregation.” *Journal of Mathematical Sociology* 1:143-86.

Schwartz, D. 1993. “Antecedents of Aggression and Peer Victimization: A Prospective Study.” Paper presented at the biennial meeting of the Society for Research in Child Development, March 25-28, in New Orleans.

Schweitzer, F., J. Zimmermann, and H. Muhlenbein. 2002. “Coordination of Decisions in a Spatial Agent Model.” *Physica A: Statistical Mechanics and its Applications* 303:189-216.

Scott, Craig R. 1999. “Communication Technology and Group Communication.” In *The Handbook of Group Communication Theory & Research*, edited by Lawrence R. Frey, Dennis S. Gouran, and Marshall Scott Poole, 432-72. Thousand Oaks, CA: Sage.

Seeger, M. W., T. L. Sellnow, and R. R. Ulmer. 1998. “Communication, Organization, and Crisis.” *Communication Yearbook* 21:231-76.

Seibold, D. R., M. A. Heller, and N. S. Contractor. 1994. “Group Decision Support Systems (GDSS): Review, Taxonomy, and Research Agenda.” In *New Approaches to Organizational Communication*, edited by B. Kovacic, 143-68. Albany: State University of New York Press.

Siegel, J., V. Dubrovsky, S. Kielser, and T. W. McGuire. 1986. “Group Processes in Computer-Mediated Communications.” *Organizational Behavior and Human Decision Processes* 37:157-87.

Sharma, R., M. Yeasin, N. Krahnstoever, I. Rauschert, G. Cai, I. Brewer, A. MacEachren, and K. Sengupta. 2003. "Speech-Gesture Driven Multimodal Interfaces for Crisis Management." *Proceedings of the IEEE* 91:1327-54.

Silk, E. M., and C. Schunn. 2008. "Core Concepts in Engineering as a Basis for Understanding and Improving K-12 Engineering Education in the United States." Paper presented at the National Academy of Engineering/National Research Council Workshop on K-12 Engineering Education, August 19, in Washington, DC.

Silverman, D. 1998. "Qualitative Research: Meanings or Practices?" *Information Systems Journal* 8:3-20.

Slater, P. E. 1958. "Contrasting Correlates of Group Size." *Sociometry* 21:129-39.

Slocum, T. A., C. Blok, B. Jiang, A. Koussoulakou, D. R. Montello, S. Fuhrmann, and N. R. Hedley. 2001. "Cognitive and Usability Issues in Geovisualization." *Cartography and Geographic Information Science* 28:61-75.

Slotta, J. D., and M. T. H. Chi. 2006. "Helping Students Understand Challenging Topics in Science through Ontology Training." *Cognition and Instruction* 24:261-89.

Slotta, J. D., M. T. H. Chi, and E. Joram. 1995. "Assessing Students' Misclassifications of Physics Concepts: An Ontological Basis for Conceptual Change." *Cognition and Instruction* 13:373-400.

Strauss, Anselm C., and Juliet M. Corbin. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Thousand Oaks: CA: Sage.

Tao, Ping-Kee. 1999. "Conceptual Change in Science through Collaborative Learning at the Computer." *International Journal of Science Education* 21:39-57.

Taylor, S.J., & R. Bogdan. 1998. *Introduction to qualitative research methods: A guidebook and resource.* Hoboken:NJ:John Wiley & Sons Inc.

Tazewell Elementary School. 2010. "Crisis Management Plan." http://tazewell.k12.va.us/schools/tes/crisismanagement.pdf (accessed December 3, 2010).

Tan, Felix, and Darshana Sedera. 2007. "Conceptualizing Interaction with ERP Systems Using Adaptive Structuration Theory." Paper given at the International Conference on Information Systems, December 9-12, Montreal, QC.

Thomas, E. J., and C. F. Fink. 1963. "Effects of Group Size." *Psychological Bulletin* 60:371-84.

Thompson, K. M. 2002. "Variability and Uncertainty Meet Risk Management and Risk Communication." *Risk Analysis* 22:647-54.

Tuler, Seth. 2000. "Forms of Talk in Policy Dialogue: Distinguishing between Adversarial and Collaborative Discourse." *Journal of Risk Research* 3:1-17.

Tversky, B., J. B. Morrison, and M. Betrancourt. 2002. "Animation: Can it Facilitate?" *International Journal of Human-Computer Studies* 57:247-62.

U.S. Army Corps of Engineers. "Information on Hurricane Evacuation Studies." http://www.saw.usace.army.mil/floodplain/Hurricane%20Evacuation.htm#intro (accessed October 3, 2010).

Van Vliet, Hans. 2000. *Software Engineering*. West Sussex, UK: John Wiley & Sons.

Vasiliou, Alexandros, and Anastasios A. Economides. 2007. "Mobile Collaborative Learning Using Multicast MANETS." *International Journal of Mobile Communication* 5:423-44.

Vossekuil, Bryan, Robert A. Fein, Marisa Reddy, Randy Borum, and William Modzeleski. 2002. *Final Report and Findings: Implications for the Prevention of School Attacks in the United States.* Washington, DC: United States Secret Service and United States Department of Education.

Wahle, J., A. L. C. Bazzan, F. Klugl, and M. Schreckenberg. 2002. "The Impact of Real-Time Information in a Two-Route Scenario using Agent-Based Simulation." *Transportation Research Part C* 10:399-417.

Wikipedia. School Shootings. http://en.wikipedia.org/wiki/School_shooting. (accessed December 2, 2010).

Wilensky, U., and M. Reisman. 2006. "Thinking Like a Wolf, a Sheep, or a Firefly: Learning Biology through Constructing and Testing Computational Theories – Embodied Modeling Approach." *Cognition and Instruction* 24:171-209.

Wilensky, U., and M. Resnick. 1999. "Thinking in Levels: A Dynamic Systems Approach to Making Sense of the World." *Journal of Science Education and Technology* 8:3-19.

Wylie, B., G. Cameron, W. Matthew, and D. McArthur. 1993. "PARAMICS: Parallel Microscopic Traffic Simulator." Paper presented at the Second European Connection Machine Users Meeting, October 13, in Meudon, France.

VITA

Shelrie Dawn Houlton was born in Santa Fe, Texas, on November 14, 1968, the daughter of Phillip and Shirley and sister of Shannon and Phillip Jr. After her 1986 high school graduation from Santa Fe High, she attended Southwest Texas State University and earned a Bachelor of Arts in anthropology in 1997. She then attended Florida Atlantic University and graduated with a Master of Arts in geography in 2005. In January 2007, she entered the Graduate College at Texas State University-San Marcos to pursue a Doctor of Philosophy.

Permanent Address: 225 South Tropical Trail

Merritt Island, Florida 32952

This dissertation was typed by Shelrie Dawn Houlton.