MASTERS PROGRAM IN

GEOSPATIAL TECHNOLOGIES

VIRTUAL GLOBES AS A PLATFORM FOR DEVELOPING SPATIAL LITERACY

Kathryn Elizabeth Clagett

Dissertation submitted in partial fulfilment of the requirements for the Degree of *Master of Science in Geospatial Technologies*

Universidade Nova de Lisboa
Universitat Jaume I
Westfälische Wilhelms-Universität Münster

VIRTUAL GLOBES AS A PLATFORM FOR DEVELOPING SPATIAL LITERACY

Dissertation supervised by

Professor Marco Painho, Ph.D

Dissertation co-supervised by

Professor Thomas Bartoshek

Professor Michael Gould, Ph.D

March 2009

ACKNOWLEDGEMENTS

I would like to thank professors Painho, Bartoshek, and Gould for their support, feedback, and advice. Additionally, a hearty thank you goes out to Marilyn Johnston, 6th grade language arts teacher at the Rupert A. Nock Middle School in Newburyport, MA, for allowing me full access to her class and sitting down with me to brainstorm ideas for the topic of the activity. Furthermore, thanks must be given of course to the students in her classes for being so enthusiastic and helpful in letting me come into their class and work with them and doing the activities provided to them with such interest. I would also like to thank my friends and family for their support throughout this process.

Lastly, I want to thank all those passionate researchers—both those cited here as well as others—who are committed to encouraging and finding the best way to implement geospatial technologies in the classroom.

VIRTUAL GLOBES AS A PLATFORM FOR DEVELOPING SPATIAL LITERACY

ABSTRACT

Virtual globes offer a solution to the traditional obstacles of time and money to implementing geospatial technologies in the classroom as a tool since they are free and intuitive interfaces. However, little research has investigated whether virtual globes are capable of teaching spatial thinking skills as traditional geospatial technologies have been shown to do. By comparing the work of 6^{th} grade students using either paper maps or a virtual globe application to investigate the country of Ghana, this study seeks to quantify the differences in learning of spatial skills between each method. Specifically, this research looks at the differences in results, approaches, and how the students' previous exposure to geospatial technologies affects each of these variables.

KEYWORDS

K-12 education

Spatial literacy

Teaching with geospatial technologies

Virtual globes

ACRONYMS

AEJEE-	ArcExplorer Java Education for Educators
ANOVA –	Analysis of variance
ESRI –	Environmental Systems Research Institute
GIS –	Geographic Information System(s)
GPS –	Global Positioning Systems
K-12 –	Kindergarten (age 5) through twelfth grade (age 18) according to the United States educational system
KML –	Keyhole Markup Language
NASA –	National Aeronautics and Space Administration
NCGIA –	National Center for Geographic Information and Analysis
NRC –	National Resources Council
NSES –	National Science Education Standards
USD –	United States Dollars

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

1 Introduction

1.1 Spatial literacy

Today, our daily lives are inundated with spatial data. One must only turn on the nightly news to be zoomed into the geographical area of interest for the next featured story, open a magazine to see maps of demographic data, or visit a retail outlet's website to be shown a map of store locations. It has been estimated that 70-80% of data have a spatial component—that they are mappable (Downs and DeSouza 2006). Technological innovations such as geographic information systems (GIS) and online mapping applications have ensured that this spatial data is more and more likely to actually *be* mapped.

While mapping can be an effective method for communicating a large volume of data—think of the proverb of a picture being worth a thousand words—the effectiveness of this communication is dependent on the *spatial literacy* of the observer. Spatial literacy can be defined as a "set of abilities related to working and reasoning in a spatial world" that allow us to comprehend maps, pictures, and spatial data, the same way we are taught to understand numbers, text, and logic (Goodchild 2006 para. 6). Since we are confronted with spatial information from the time we can conceptualize what we see in front of us, it is important that improving spatial literacy begins at an early age.

Spatial literacy is a vital skill and one that could be taught through traditional classroom learning tools such as books and chalkboards, but students today are exposed from an early age to spatial data in a digital form so it seems appropriate that digital platforms also be part of the learning process. Although the prevalence of this technology is part of the 'problem' necessitating education in spatial skills, this technology has the potential to also be a part of the 'solution' when it is used to teach students the life-long skill of being able to reason spatially. Research investigating whether geospatial technologies are an effective means of teaching spatial skills is important to help justify their use in the classroom.

1.2 Geospatial technologies in the classroom

Geospatial technologies can be defined as any technology that aids in the visualization and analysis of data by showing the location of various phenomena on the Earth's surface. This includes global positioning systems (GPS), GIS, and remote sensing. Since the early 1990s, research has explored the use of geospatial technologies in the classroom. In fact, in 1992 the Environmental Systems Research Institute (ESRI)—one of the premier GIS corporations in the world—launched an educational initiative, the same year they introduced ArcView GIS 1.0, their first graphical user interface GIS (Fitzpatrick 2001). From these early years, interest in using geospatial technologies in the classroom has grown along with the number of conferences, research, and school standards addressing this topic. Despite this positive growth, GIS has still been found to have been adopted by less than 1 percent of American high schools (age 14-18) (Kerski 2001).

Before delving further into the use of geospatial technologies in the classroom it is important to make a distinction between teaching *about* geospatial technologies and teaching *with* geospatial technologies. Each method has different means and ends. For teaching *about*, the primary goal is for the student to learn the software, which is best achieved by spending time teaching about the ins and outs of the technology. Alternately, in teaching *with* the geospatial technologies the goal is for the student to learn and understand the content of some (or many) academic discipline(s) using the software as a platform for this learning. Class time should be primarily spent giving the students the freedom to explore the academic content rather than teaching them the application itself. This research focuses on the use of geospatial technologies as the latter, where the technology is principally a *tool* for the student to gain knowledge about other topics.

Furthermore, this study will focus specifically on the use of these technologies in pre-university schools, referred to in the United States as K-12, for kindergarten (age 5) through twelfth grade (age 17-18). This was a conscious decision not only to focus the scope of this research, but also because K-12 education serves a very different student body than is found in universities. In universities students typically have elected to take a certain course whereas in K-12, the students usually do not have as much or any freedom for choosing their classes. This means that K-12 classes end up with a more diverse cross-section of students with some students who might have an interest in geographic technologies but likely many more who have no known interest or previous exposure. Additionally, at universities students are likely to have specific interests and be on a certain track, whereas during the K-12 years these interests are still developing, making this a particularly appealing group for this research. Lastly, in reference to the issue of teaching *about* versus *with* geospatial technologies, teachers are much more likely to use geospatial technologies as a tool in the K-12 arena than in universities, where the situation is reversed and more often a geospatial technology *is* the end, rather than the means to another end (Kerski 2001). It has been argued that this is logical as university students are more likely to want to learn GIS skills for job possibilities, while for K-12 students, GIS serves best to educate students on more general topics (Keiper 1999). Clearly there are many differences between the contexts with which geospatial technologies are taught in universities or during the K-12 years; this supports the decision of this study to focus on applications in the latter.

While the second chapter of this study will provide an exhaustive literature review of research in the field, it is worthwhile to overview the scope of research in this chapter to present a framework for this case study. In the following sub-sections a brief overview will be given to the advantages and disadvantages of using geospatial technologies as a tool in the classroom as suggested by previous research.

1.2.1 Advantages to using geospatial technologies

Since the beginning of the use of geospatial technologies as a teaching tool, research has investigated many aspects of their use in the classroom. These studies have offered a number of suggestions based on speculation as well as quantitative/qualitative research of how the use of geospatial technologies can benefit the learning experience in a classroom. Again, a more complete summary of perceived advantages will be offered in Chapter 2.

The benefits of the use of geospatial technologies are as wide ranging as the implementations. As mentioned, generally speaking geospatial technologies are used to ask or answer some sort of spatial question, although this question can be related to any number of fields. In this sense, the technology fosters geographic skill, knowledge, and enthusiasm by piquing a student's spatial thinking capabilities and increasing their interest in geography via an engaging interactive platform. Likewise, geospatial technologies encourage enthusiasm, skill, and knowledge generally, not just in terms of geography by integrating data from many disciplines to model our complex world. Moreover, when students are using a mapping program as a tool, they are also picking up valuable technological skills. Additionally, students love using these platforms and they are therefore seen as highly motivating for students since these tools get students interactively involved in their learning. Geographic platforms are consequently valuable in the classroom by getting students interested and excited about learning.

Teachers like using geospatial technologies in the classroom as well, since these tools fit so nicely into modern teaching pedagogies. These new pedagogies move away from rote memorization and towards constructivist styles where the teacher acts more a guide while students explore what is most interesting to them. Constructivist methods also encourage project-based learning, something that geospatial technologies can easily be used for. These technologies also cater to different learning styles by working well for students who learn better with hands-on work or visual aides. Geospatial platforms also help teachers' methods fit recent teaching standards that will be discussed in following chapter. What's more, geospatial technologies are often a powerful way for classes to connect to the community since many of the most successful projects have been based in the community using local data and may even culminate in a presentation to the public (Fitzpatrick 2001). Clearly there are a wide variety of compelling arguments on the teacher's side to use the use geospatial technologies in the classroom.

1.2.2 Disadvantages to using geospatial technologies

Given the many excellent advantages cited for the use of geospatial technologies, it may seem curious that teachers have still been so slow to adopt these platforms. Unfortunately, the benefits for using this technology in the classroom are checked by several formidable disadvantages.

At the most fundamental level, to use a geospatial technology you need hardware, software, and time. Hardware is required for any geospatial platform and frequently the requirements in terms of memory and processing speed necessitate expensive computers. The cost of software depends on exactly what package is being used, but top of the line desktop GIS can be extremely costly. Again, depending on the software, the applications interfaces may also be counterintuitive and difficult to learn. This means time is required for both the teacher and student to learn the application. Formal training seminars for teachers in using geospatial technologies in their classrooms may invite additional costs to the schools for substitutes or fees as well as often costing the teacher time out of their personal life. Clearly, the implementation of a geospatial technology can lead to a large consumption of time and money.

Furthermore, geospatial technologies must not be thought of as an educational panacea. Teachers cannot simply use the tool and expect that students are reaping all the previously mentioned rewards. More than just teaching with geospatial technologies, teachers need to teach *effectively* with geospatial technologies which requires that they have finely honed critical and spatial thinking faculties themselves. To teach effectively, teachers also need to feel that they have support in their endeavors—from administrators, from other teachers, and technically. For teachers, the very fact that geospatial technologies can be applied in so many different ways across many subjects may be a disadvantage—they may not be sure where to start when it comes to implementing them (Fitzpatrick 2001). This range of possible applications may not be the only problem; the book *Learning to Think Spatially* even goes so far to say that, "without software that suits the specific needs and constraints of K-12 education, the use of GIS in the curriculum will be severely limited" (Downs and DeSouza 2006 p. 213). Despite the many positives, these hindrances may be enough to keep the population of teachers who use geospatial technologies in their classrooms at a minimum. However, a new generation of geospatial technologies is evolving—one that is fostered by the ubiquity of the Internet in today's classrooms; virtual globes have the potential to ameliorate some of the major problems found with implementing geospatial technologies while maintaining their advantages.

1.3 Virtual Globes and Google Earth

While any online map of the world can technically be though of as a 'virtual globe,' the term is most often used to refer to 3D representations of the world such as Google Earth, ArcGIS Explorer, and NASA World Wind. Although this concept has been around since the late 1990s when it was a pet project of then US vice-president Al Gore, actual public applications were not available until 2004 when NASA's World Wind was launched (Butler 2006). The next year Google released its version of a virtual globe, Google Earth, which became immensely popular, having been downloaded more than 100 million times in 2006 alone (Doering and Veletsianos 2007). Each of the available virtual globes offers different features and benefits but Google Earth has been the most popular with the general public. As this study uses Google Earth as its platform for research, from this point forward, the term 'virtual globe' will be used interchangeably with Google Earth, unless noted otherwise.

Virtual globes were brought into the spotlight through the ease with which they could share important and up-to-the-minute information in the wake of natural disasters. Shortly after the launch of Google Earth Hurricane Katrina hit New Orleans. Amidst the tragedy one silver lining was a greater public exposure to the importance of geospatial technologies both in providing the rescue effort with the necessary data to do their jobs effectively and as a platform for the public to learn more about what had happened. As Michael Goodchild put it, "no one following the event of August and September 2005, in the days immediately before and after Hurricane Katrina, could have missed the message that GIS and spatial data were of absolutely critical value. Anyone with Internet access could download a thin client and use the Google Earth service to see the situation in new Orleans, Louisiana at submeter resolution wherever they were located on the planet" (Goodchild 2006 para. 3). This could be construed at the tipping point for virtual globes, when the general public could see a real practical application for this mapping platform.

Google Earth (Figure 1) is available at three licensing levels each with increasing capabilities. The free version, which is the most common, includes some data and some basic 'advanced' functions such as being able to measure distances, create basic KML (Keyhole Markup Language, the programming language for Google Earth files), and use the pilot simulator. The two licensing levels above the basic, Plus and Pro, allow for importing points from Excel or a GPS as well as faster processing speeds and better support. Although Google's education initiative is generous in giving free Pro licenses to schools, since the basic level is the most frequently used, this study will focus on this level of licensing.

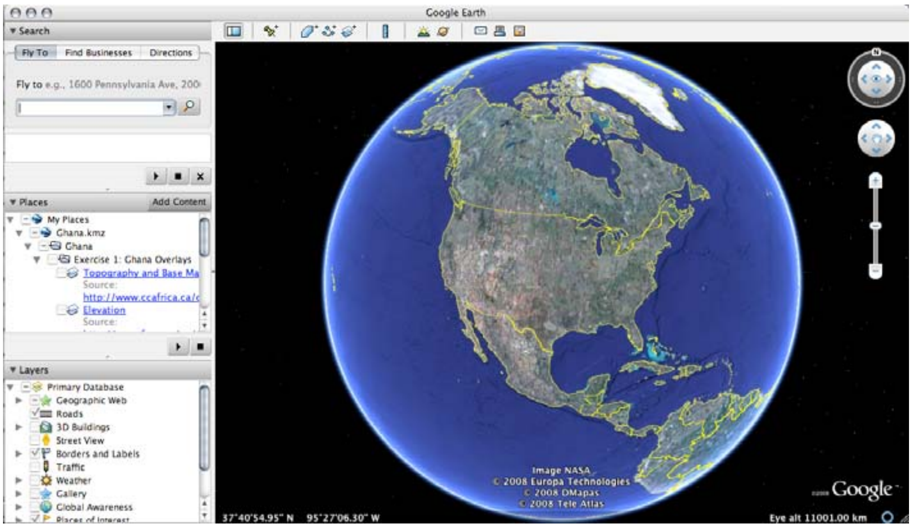


Figure 1: Screenshot of the basic level of Google Earth.

1.3.1 Advantages of virtual globes over traditional geospatial technologies

One of the main reasons that virtual globes merit further analysis as a teaching tool is that researchers have suggested that platforms such as Google Earth could be the answer to many of the cited disadvantages of other geospatial technologies (Doering and Veletsianos 2007; Patterson 2007). For example, in terms of technology, Google Earth is a much more intuitive interface than most desktop GIS so less time and money needs to be spent on training both teachers and students. Moreover, whereas desktop GIS can require expensive software, most virtual globes are available for free and require only the Internet, which is ubiquitous enough to be found in 99% of schools (Baker 2005).

These benefits come at little cost to the implementation. Teachers rarely make use of some of the more advanced functions of GIS since those who use it in the classroom most frequently use it for only one lesson a year (Kerski 2003). Therefore virtual globes such as Google Earth retain the functions of a GIS most used by teachers in a much simpler interface. In fact, companies like ESRI see virtual globes as a boon to their business by providing a gateway into the world of geospatial technologies for both teachers and students (Butler 2006). Applications such as Google Earth can also open doors for students that will lead them ask more sophisticated spatial questions and seek the tools to answer these questions. While Google Earth may lack analytical functions, visualization—one of its most powerful uses—is in some ways *better* supported in Google Earth than in GIS. For instance, Google Earth supports time animations that may make Google Earth more visually stimulating than traditional desktop GIS for students who have grown up on computer and video games. Additionally, just as many, if not more, online website and forums exist for Google Earth as for GIS so that teachers can get help with the technology as well as download actual lessons. Furthermore, Google Earth makes it very easy for students to share data not only with each other, but also with the world, endowing students' work greater meaning. Tools such as Google Earth do well to ameliorate some of the problems of more traditional forms of geospatial technologies while still maintaining their value. Again, these advantages will be analyzed more in depth in the following chapter.

1.3.2 Disadvantages of virtual globes over traditional geospatial technologies

Despite these advantages, there are also some disadvantages over traditional geospatial technologies. Firstly, despite the ubiquity of the Internet in the classroom, Google Earth requires a fairly fast Internet connection for the images to load quickly, which may not be available in all classrooms. Again, as mentioned, most virtual globes lack more sophisticated analysis tools, which means that if students want to ask more in depth questions, they may not have the necessary tools available to them—this, then, may limit the degree to which critical thinking capabilities are honed by geospatial technologies. Additionally, the cartographic capacity of virtual globes is typically much less than desktop GIS meaning that, among other drawbacks, students may be able to look at phenomena on the face of the 3D Earth within the application, but not be able to create particularly visually appealing 2D output maps.

In some ways the scope of Google Earth may be too big—teachers may find that students are easily distracted by virtual globes, wanting to look at their own houses and zoom around clicking on placemarks rather than attending to their assignments. This, and the fact that students are by necessity connected to the Internet and therefore may try to check email or do other things not related to the assignment, may mean that is it harder for teachers to control their class when using Google Earth than with other desktop GIS (Kerski 2007). While there are some good advantages to using Google Earth, it is important to also weigh the disadvantages to make sure that Google Earth is the most appropriate application for the objectives of the classroom assignment.

1.4 Research context and objectives

The previous sections have served to provide a context for the research presented in this thesis. To reiterate, geospatial technologies have been suggested as a viable way to help foster spatial literacy, or the ability to reason spatially. This skill is vital in today's world where we are confronted with the need to understand spatial data on a daily basis. Geospatial technologies in general have been used in educational setting since the early 1990s and research on the topic commenced concurrent to this time. Previous research has shown that geospatial technologies can be a valuable asset to a classroom by encouraging critical thinking and enthusiasm for both geography and in general, increasing the technological capabilities/awareness of the students, connecting the students to the community, and fitting in well as a tool of modern teaching pedagogies. Despite these advantages, the use of geospatial technologies have also been criticized for the amount of time and money necessary to implement them, the support required for teachers to be able to use these platforms, and the fact that none of the previous cited advantages may be realized if the teaching is not effective. However, new technology has emerged in the form of virtual globes such as Google Earth that may be a boon to the use of geospatial technologies as a tool in the classroom by helping ameliorate some of the disadvantages while, as this case study seeks to investigate, maintaining the advantages.

This study seeks to look specifically at quantifying the effect of using Google Earth as a teaching tool in the classroom. As previously mentioned, this research will focus not on examples where Google Earth is taught explicitly, with an end goal of the students learning how to use the application, but rather when Google Earth is used as a tool through which students learn another subject. Additionally, this research will look specifically at using Google Earth in the K-12 setting where teachers need tools that appeal generally to their student body, which represents a wider cross section of students than is typically found in higher education.

Previously published work on the use of Google Earth has either merely discussed suggested advantages, or sought to qualitatively define the advantages to using Google Earth (Butler 2006; Lisle 2006; Doering and Veletsianos 2007; Kerski 2007; Patterson 2007). While this research has been very encouraging in regards to the usefulness of implementing virtual globes, this area of study is lacking in a quantitative analysis. This research hopes to fill this gap by providing empirical research to look at the effect of using Google Earth in the classroom. This quantification will allow us to understand how effective Google Earth is as a tool for teaching and encouraging spatial thinking, thereby helping address our need for spatial literacy skills.

This study will focus on the use of Google Earth as a teaching tool in a 6th grade classroom in a small city in the northeastern United States. The students will spend this year in their language arts class writing to a woman in the Peace Corps program in Ghana. As a way of acquainting the students with this country, the teacher planned on using one class period to introduce the country to her students. This was seen as an excellent opportunity to introduce Google Earth to the class by using this tool to teach the students about Ghana. For the sake of this study, students were asked to complete this activity either with paper maps or with Google Earth in order to compare results. During this exercise, students using either method filled out a worksheet in pairs to answer the questions posed to them. This worksheet was used as the basis for the research by comparing answers between the two methods. The exercise consisted of two main sections, the first of which asked the students to look at different maps of Ghana and determine where they would put the capital if it were up to them while the second asked the students to read about several locations in Ghana and then read letters from six students in Ghana to try to match the Ghanaian students with where they are from based on clues in the letters. Lastly, the following day students filled out a questionnaire describing their previous exposure—before the exercise—to various types of geospatial information as well as asking those students who used Google Earth in the exercise whether they enjoyed using it, what the enjoyed about it, and whether they would want to use it again either at home or in class. Additional feedback was also received from the teacher of the class to elicit her opinion on how the day went.

This research seeks to quantify the differences in learning between students who used paper maps and those who used Google Earth for this exercise to analyze the benefits and drawbacks of Google Earth as a teaching tool in the classroom through the comparison of the worksheet results. Furthermore, this study will address if and how previous exposure to maps and geographic technologies affects the outcome of this research by comparing worksheet results with the results of the questionnaire. This research will attend to three main hypotheses:

- H_1: Scores for exercise 1 and 2 separately are the same for both techniques
- H_2: Students demonstrate the same learning methods for paper maps and Google Earth
- H_3: Previous exposure to maps and geographic technologies will not affect score on either exercise

1.5 Overview of document

Chapter 1 of this thesis has sought to provide a context to the research objectives by reviewing the importance of educating the public in spatial literacy, with geospatial technologies offered as one tool to help enrich our ability to reason spatially. This chapter then overviewed the main suggested advantages and disadvantages of using geospatial technologies in the classroom. From there, this chapter addressed specifically the benefits and problems virtual globes, focusing on Google Earth, which will be the application in question in this study. Lastly, this chapter overviewed the objectives of this research, laying out the hypotheses explored by the research.

The rest of the paper will be structured as follows: Chapter 2 will provide a history of the use of geospatial technologies as a tool in K-12 classrooms as well as an in depth literature review of this topic before looking specifically at the small body of academic work that has focused specifically on Google Earth and virtual globes; Chapter 3 will overview the specific methodology of this study, explaining the details of the exercises done by the students as well as other practical details of the experiment; Chapter 4 will present the results of the study through a series of statistical tests; Chapter 5 will discuss these results, providing possible reasons based in previous research as well as speculation for these results; and finally, Chapter 6 will offer a concluding summary of this paper as well as discuss suggested areas for future research.

2 Literature Review

The literature relevant to this topic is wide ranging. In the general realm of research concerning geospatial technologies in education, a large variety of approaches and disciplines are represented varying from issues of spatial cognition (Downs and DeSouza 2006) to assessments of very specific desktop GIS analyses (Beatty 1996; Stewart, Schneiderman et al. 2001). For the sake of this literature review, the focus will be narrowed to articles discussing the use of geospatial technologies explicitly as a curricular tool and only in K-12 settings. This still leaves a large body of literature, and while this review will try to be as thorough and complete as possible, undoubtedly some sources will be omitted either due to restricted access to this resource, the redundancy of the content to other academic papers, or the accidental oversight of the researcher. This review will break the topic down into four constituent parts of teaching with geospatial technologies: technology, support, teaching, and student experience. At the end of this review of geospatial technologies in the classroom in general, focus will be given to the small body of developing research in regards to virtual globes. The information provided in this chapter will serve as a basis for arguments related to the specific experiment conducted in this thesis, as presented in Chapters 3-6.

2.1 Review of issues with implementing geospatial technologies

2.1.1 Technology

Obviously one of the fundamental issues when it comes to using a GIS or other geographic technology in the classroom is how to obtain and use the technology involved. Surprisingly, considering how essential technology is to the issue, it is a topic that is generally only touched upon in research.

Hardware is the first issue to come to mind; you absolutely must have at least one computer if you are to use geospatial technologies in the classroom, be it a laptop, desktop computer, or GPS receiver. Luckily, computers are a fixture of almost any classroom today; a 2001 study found that 93% of schools polled at random had a computer center and 80% of the schools had computers in more than three-quarters of their classrooms (Donaldson 2001). Despite the seeming ubiquity of computers, there is a socioeconomic difference between schools with computers and those without; it has been found that as the ratio of computers to students drops, the number of free or reduced lunches offered (a measure of the household income of the student's family) increases (Baker 2000). It is of course also necessary to consider the quality of the hardware—desktop GIS programs, for instance, can eat up memory on a computer and students may get bored or frustrated if the computers won't act as quickly as their thinking (Keiper 1999). The number and type of computers available will limit, but not necessarily prohibit, a teacher's ability to use a geospatial technology in their classroom. Although today many schools are already outfitted with computers, it is important to consider that for some schools, appropriate hardware may still be an issue.

A further issue with both hardware and software is cost. According to a 1997 study polling teachers who used GIS, the cost of start-up—inclusive of hardware and software—was slightly less than $6,000, which is a formidable amount of money, and likely an overestimation given that this study is over 10 years old (Audet and Paris 1997). As with any technology, the costs have of course lessened over time and now some GIS applications are as attainable as virtual globes, cost-wise. One possible solution for dealing with cost when it is an issue is to partner with a local university for computing facilities and training, a strategy common in implementation studies (Meyer, Butterick et al. 1999; Patterson, Reeve et al. 2003). In other cases, researchers spoke of the reduced cost software licenses available through ESRI's education department (Laituri and Linn 1999). These examples, of course, are drawn mainly from discussions regarding the use of desktop GIS—unsurprisingly, the issue of cost drops out of research when that study is focused on webGIS, virtual globes, or other online mapping platforms, which are generally free.

In regards to geospatial technologies, there are several different possible applications or programs that can be used. Early efforts to integrate these technologies focused on desktop GIS, but now this is certainly not the only option. Various organizations have created less complicated desktop GIS versions that are specifically customized for educational applications (Baker 2000; Schaefer 2003). Additionally, webGIS are available in simple web browsers, with no separate application needed (Kerski 2007). Finally, virtual globes are also an option, which are typically stand alone applications (Kerski 2007; Patterson 2007). Clearly there are many options for teachers to choose from, all of which have been explored in research.

Perhaps the most important issue with software is its level of ease of use, which is not by definition, but oftentimes, also a measure of its sophistication. While the issue of time in relation to this topic will be addressed further in the context of teaching, it is important to also consider here. Complicated desktop GIS can be very frustrating for the user—one study cites how users employed words like 'pain' and 'suffering' to describe their experience working with GIS (Kerski 2003). Battersby *et al.* remark that GIS packages not designed for educational use are perhaps not the best choice for lower grade levels (Battersby, Golledge et al. 2006). The interface may not be something that either teachers or students are familiar with and oftentimes the design of the interface is not particularly conducive to quick learning since it may have unfamiliar button symbology and analytical functions hidden in toolboxes or menus. Again, as studies have moved away from looking primarily at desktop GIS applications, the matter of complexity has largely been ignored since it is no longer an issue.

Another important topic related to technology is that of data, which is just as fundamental to the use of geospatial technologies in the classroom as hardware and software. The acquisition of the appropriate data sets can be costly and difficult (Audet and Paris 1997) although as time has progressed data has become more prevalent and easier to acquire; already sites like the United States Census Bureau offer vast amounts of demographic data and shapefiles for many scales of geographic division. For most teachers, having students work with data is one of the most important advantages of using a geospatial technology—the students can learn about data, how data works together, and how to analyze data (Kerski 2003) as well as to question where data comes from and what biases may be inherent in that data (Merrick and Besser 2005; Chandler and An 2007). In fact, one study found that there were significantly improved changes in attitude towards making personal decisions from scientific data as well as analyzing and picturing scientific data by those students who used GIS to do an experiment versus those who did not (Baker and White 2003). Despite the challenges of acquiring the necessary data, having interesting high quality data can be a major factor in effectively implementing geospatial technologies.

2.1.2 Support

It's important that teachers not feel alone when trying to implement a geospatial technology into the classroom. As mentioned, just setting up a school to be ready to do a GIS activity requires many resources both in terms of time and money, so ideally teachers need support both technically and personally.

Firstly, teachers need to feel that they have help with the technical aspects of geospatial technologies. This may mean having a capable person around to help out as an extra set of hands during activities; one study found that teachers were much more likely to have actually used GIS in their classroom if they had a technical support person to help them (Kerski 2001). Beyond physically having someone there, the Internet also facilitates technical help; tools like listservs (Bednarz 2004) and websites can be great ways for teachers to connect with professionals or with fellow teachers. As mentioned, technical help can also come from forming partnerships with organizations in the local community. Several studies partnered with local organizations either for data (Keiper 1999), facilities (Joseph 2004), or graduate students willing to help out (Laituri and Linn 1999). So while technical help is a vital factor in the success of geospatial technology implementation, resources are available for almost any teacher to get the help they need if they are willing to seek it out.

Beyond support with the technical aspects, personal support is also important to achieving success. Oftentimes success doesn't just depend on the motivation of a teacher, teachers also need institutional support for funding of technology and training; in one study teachers interviewed complained that the most time-consuming part of using geospatial technologies was arguing with people of power in their schools (Bednarz 2004). In other cases it has been seen that the support of officials such as the school principal is perhaps the deciding factor for teachers being given the go-ahead to use geospatial technologies in their classrooms (Kidman and Palmer 2006). As Kerski concisely puts it, beyond the one implementing teacher being enthusiastic and willing, "for GIS to be effective, schools must build an environment of curiosity about investigating the world" (Kerski 2003 p. 136). Teachers are more likely to actually use geospatial technologies in their classes if they feel that the administrators and other teachers are backing their efforts.

2.1.3 Teachers and teaching

Teachers, as most often the one to initiate the integration of geographic computer platforms into their classes, are perhaps the most important factor in successful implementation. As the most integral part, teachers have also been found "to be 'the weakest link' and a serious component limiting diffusion of GIS" (Bednarz 2004 p. 198). Due to the importance of this issue within the greater topic, this section will give ample attention to teaching, looking at what teachers needs to learn before they start a project, what teachers can get out of using geospatial technologies, and how they might implement it in their classroom.

Training and preparation is the first issue to consider in regards to teaching with GIS since teachers need to have the skills to teach their students effectively. Unfortunately, training takes up time, which, in a survey of teachers, was the biggest challenge that they faced in integration (Kerski 2003). As pre-service teacher training is virtually non-existent, teachers need to find time either within their school year or during their personal time to attend training seminars or train themselves (Donaldson 2001; Kerski 2001; Joseph 2004). Teachers also need more than just technology skills training, they need to be taught how to teach spatial concepts and how to integrate exercises into the curriculum (Laituri and Linn 1999; Joseph 2004; Baker 2005). Teachers need to be educated on exactly how to create materials that take advantages of the technology; while it is wonderful that geospatial technologies offers so many options for implementation, this characteristic can also be a hindrance since teachers may have so many options that they feel overwhelmed by the choice (Fitzpatrick 2001). After the training, teachers also require time in their curriculum to integrate geospatial technologies and actually teach with it. Clearly proper preparation for implementation is vital to the success of the activity, but this can also be a time-consuming process.

Another topic that may be a problem for some teachers is the issue of teaching pedagogies. Traditional teaching methods have revolved around rote memorization, with the teacher directing every aspect of the class; new teaching practices eschew these methods as outdated, inefficient, and ineffective (Baker 2001). Many of the new methods fall under the heading of constructivism, or the idea that knowledge is best created not through observation but through interaction, with activities that almost mimic that of on-the-job experiences (Keiper 1999). The idea behind constructivism is that students focus on problem solving and developing autonomy in a more project-based environment. Instead of telling the students what to do, teachers act as a guide, letting the students explore and direct their own learning. Geospatial technologies can be the perfect complement to these teaching methods by facilitating interdisciplinary study, project-based learning environments, and an inquiry analysis approach. However, for teachers used to the old methods, this may require a significant change—in fact the use of geospatial technologies has actually been shown to change the way teachers teach to fit more these modern pedagogies (Laituri and Linn 1999; Kerski 2001; Joseph 2004). If teachers are willing to make the shift to a style that allows more for the integration of geospatial technologies, however, the rewards can be great.

Firstly, geospatial technologies provide an excellent platform for different types of learning. These applications allow for an extremely high level of interaction between students and data, and are an excellent tool for visualization. This means that tools like these offer an alternative for students who learn better visually or kinetically, catering to these learning styles not piqued by traditional methods (Sanders, Kajs et al. 2002; Kerski 2003; Patterson 2007). Furthermore, the very nature of a geospatial technology as a platform for visually bringing together traditionally disparate data sets means that these programs can foster interdisciplinary thinking, modeling our world by showing the spatial relationship between many different phenomena across academic disciplines. These spatial tools can allow students to understand their content in a whole new light.

Computer applications such as these can also be a valuable instrument for teaching spatial thinking. Students can visualize relationships between phenomena over space and learn to explore correlations and relationships that might not be immediately obvious. These tools may even lead students to investigate spatial patterns and relationships above and beyond what the teacher initially has planned (Fitzpatrick 2001). Spatial thinking skills are important to develop because they are not necessarily a stand-alone skill: it has been shown that spatial thinking ability is highly correlated with math and science skills (Battersby, Golledge et al. 2006). Actually attaining these positive outcomes may be difficult for teachers—in order to teach spatial thinking, it is vital that the teacher's understanding of these concepts is also strong (Meyer, Butterick et al. 1999; Bednarz and Bednarz 2004; Doering and Veletsianos 2007). Unfortunately, training in spatial thinking is frequently left out of teacher training in using geospatial technologies, which often incorrectly assumes that teachers already have these capabilities. If teachers are not spatially literate, how can they be expected to teach their students to analyze and explore spatial patterns and processes (Page 2003)? Lastly, for the teaching of spatial thinking to be effective, it has been found that teachers must be explicit about the fact that they are teaching their students spatial thinking—you cannot assume that just because a student uses a GIS or other technology, they will immediately understand that they are learning about spatial relationships (Meyer, Butterick et al. 1999; Baker and Bednarz 2003). Spatial thinking *can* be one positive consequence of implementing geospatial technologies, but the teacher plays a large role in whether this goal is met.

Schools standards can be both an asset and a handicap when it comes to using geographic computer platforms. Although there are no national standards for years K-12 that require the use of geospatial technologies, there are standards written either with these tools in mind or where they would serve as a perfect means to execute those standards (Baker 2005). For example, GIS addresses the National Resources Council science standards, those of the International Society for Technology in Education, as well as the inquiry-based approach advocated for by the National Council for the Social Studies (Kerski 2003). GIS is also the only tool that helps meet all of the standards set out by the National Geography Standards of 1994 (Joseph 2004). Besides these standards, states are also putting pressure on school systems to use this technology in their classrooms (Patterson, Reeve et al. 2003). Surprisingly, many teachers do not see meeting standards as a primary motivator for implementing geospatial technologies, in fact, with national standards such as *No Child Left Behind* requiring that educators teach to specific tests, some teachers actually see implementing these programs as something they don't have time for, rather than as something that could help them prepare for these tests (Kerski 2001). While geospatial technologies can help teachers meet suggested standards, again, realizing this goal depends largely on how effective the teacher is at integrating these tools into the curriculum.

While the United States has seen only this more indirect promotion of geospatial technologies in the classroom through standards, other countries have seen more forceful requirements enacted that are more explicit about the use of GIS in schools. For example, in

Germany, the German Association for Geography has laid out an entire progression of successively more advanced GIS skills that students need to have; students in some regions of the country are expected to be able to actually use a GIS by the time they leave grade ten (age 15) (Siegmund, Viehrig et al. 2007). Additionally, unlike in the United States where most training in geospatial technologies is aimed at in-service teachers (Kerski 2001), in Germany courses are offered to pre-service teachers on how to integrate various forms of geospatial technologies into their teaching. GIS is already used by many schools in Germany and researchers in the country hypothesize that "in the near future, GIS will be used in all schools across Germany" (Schaefer 2003 para. 15). The use of GIS is not just relegated to the West, either; currently, GIS is being used of 25% of high schools in Taiwan (Kerski 2008b). Although these are just a few examples, it speaks to the fact that globally GIS has been adopted and supported at different levels in different countries.

Teachers can use geospatial technologies in nearly every discipline across the curriculum. There are no paucity of examples of how teachers have integrated geospatial technologies in rewarding and interesting ways (Alibrandi 2003). Research has shown that teachers have been able to integrate geospatial technologies into nearly every academic discipline from language arts to geography, although one study shows that science teachers (followed closely by social studies teachers) are the most likely to use it (Kerski 2001), a statistic reflected in the body of research reviewed for this study where most examples came from either science or social studies classrooms. Several of these studies advocate for the use of geospatial technologies in particular because of their ability to teach geographic concepts, even when couched in the study of other academic disciplines. Geography is getting pushed out of the curriculum and geographical technologies are one way that the subject can be taught by either reinvigorating the subject itself (Donaldson 2001) or by integrating it into other subjects (Battersby, Golledge et al. 2006). Geospatial technologies, although frequently associated with geography and science teaching, can be used effectively as a tool in nearly every discipline.

In regards to how teachers have chosen to implement this technology, there is again a wide diversity. Some teachers simply demonstrate using a GIS or a virtual globe in front of the classroom while others have every student at their own computer. Likewise, since educators aren't always sure how to make the most of the tool, some teachers choose to use it only for visualization while others may have the students doing complex analyses; the choice here depends on what the teacher is hoping to get out of the exercise or project. Teachers who use geospatial technologies in their classroom have been found most often to use GIS in only one lesson a year (Kerski 2003) although programs in Colorado (Laituri and

Linn 1999) and Michigan (Joseph 2004), for example, have been set up to encourage a multi-class, multi-year approach to integrating GIS. Several studies found that this gradual approach was best for integrating geospatial technologies. With this tactic students are introduced to increasing levels of sophistication over several years, thereby cementing not only the underlying concepts, but also refreshing the minds of both student and teacher annually on how to use the tools (Baker 2000; Joseph 2004). Moreover, it's best when the project that the students do is fluidly integrated into the normal curriculum, thoughtfully placed in such a way that one can almost think of it not as a separate GIS activity, but rather as a GIS-enhanced curriculum (Audet and Paris 1997; Keiper 1999; Kerski 2003; Bednarz 2004; Joseph 2004; Siegmund, Viehrig et al. 2007). Teachers have chosen to use geospatial technologies in a variety of different ways, largely dependent on what the teachers are capable of, what facilities they have available to them, and what they want the students to achieve.

Unfortunately, despite the versatility of this tool, teachers unfamiliar with the applications may find it hard to develop good projects. One frequent observation is the lack of pre-designed lessons for teachers (Kerski 2003; Doering and Veletsianos 2007). Since many teachers lack training in spatial thinking and in the software, it can be difficult for them to conceive of interesting projects that make the best use of the technology—some teachers may only come up with ideas that could also easily be done with paper maps (Audet and Paris 1997). In at least one study, GIS professionals created pre-designed exercises for teachers, which was found to be a major advantage for those teachers (Laituri and Linn 1999). Creating lessons takes creativity, a good knowledge of the possibilities, and time, factors that may prevent teachers from exploring the possibility of using these tools.

Geospatial technologies can be used for most subjects and in a wide variety of settings and the benefits of using geospatial technologies are attainable for almost any teacher. These tools also offer a way for teachers to simultaneously modernize their teaching methods, cater to alternate learning styles, teach spatial thinking skills, and help them meet standards. However, geospatial technologies are *not* a panacea—attaining these ends depends on how effective the teaching is. Teachers can fall prey to technocentrism, where technology is used because it exists, rather than thinking through whether this tool is appropriate and fits into the curriculum well (Bednarz 2004). Teachers must often change their approach to teaching and be careful not to simply teach *how* to use GIS or another platform, but instead teach *with* that application. Likewise, educators have to commit a lot of time and effort to creating their own lessons since training rarely includes specific ideas of how, for example, to actually integrate project-based learning and teaching to standards into their exercises (Baker and White 2003). For geospatial technologies to be successful in the classroom, teachers need to be prepared and willing to get through the hard part of learning how to use the application and how to use it effectively (Audet and Paris 1997). Despite these obstacles, studies have shown that teachers who have successfully overcome these barriers and used geospatial technologies in their classroom are extremely enthusiastic about what they can contribute to the classroom and are excited to learn more and use them again (Audet and Paris 1997; Kerski 2001).

2.1.4 Student experiences

As mentioned, one of the main advantages—and issues—in implementing geospatial technologies is that it veers from traditional teaching methods—generally exercises are more student-centered than traditional teaching approaches (Sanders, Kajs et al. 2002). Due to this, it is important to also look thoroughly at student experiences, such as what students stand to gain from using geospatial technologies and what studies have shown they actually do gain.

Geospatial technologies are thought to be an excellent tool for improving general critical thinking skills for students. In a 2003 study, students who used GIS scored significantly higher than their peers who used traditional methods and were seen to have improved their general higher order analytical thinking skills (Kerski 2003). While these findings are positive, a different—earlier—study contends that while in some cases GIS can improve critical thinking skills, it is difficult to predict consistent achievement; results have been varied and unreliable (Audet and Paris 1997). Even though quantitative results may not express better results in those who use these tools compared to those who do not, in one study the researcher commented that qualitatively, those students who used an interactive mapping program had more attractive and creative final products (Linn 1997). Regardless of quantitative results, students are certainly exposed to a unique way of thinking when they use geospatial technologies in their classrooms.

While geospatial technologies can augment the general thinking skills of a student, it is worthwhile, as with the previous section, to look specifically at spatial thinking skills. There is no doubt that using geospatial technologies increases the relevance of geographical study (West 2003) and that students will learn geography better when they are physically constructing maps themselves and interacting with the data (Linn 1997). However, quantitative results have been mixed for whether students learn spatial thinking from using geospatial technologies. Table 1 presents a summary of the various results that have come from quantitative studies measuring student learning from the use of GIS. In several of these cases students who used geospatial technologies did better at analyzing and integrating maps than their peers who used traditional methods (Wanner and Kerski 1999; Patterson, Reeve et al. 2003). Additionally, while students using GIS scored better on the exercise, when these same students who used GIS were tested with a general spatial skills test, they did not improve more than their peers in the control group (Wanner and Kerski 1999). This demonstrates that even when students are able to exhibit critical thinking skills in class, that may not mean that they are able to reapply these concepts later on, either at a different scale or even in a similar exercise (Keiper 1999; Bednarz 2004; Battersby, Golledge et al. 2006). There may also be an issue here of students not knowing enough of the basics in map-reading and spatial thinking to be able to fully internalize what they are learning (Kerski 2008a). In sum, the results of how students' spatial skills improve are mixed—students seem to gain general spatial literacy from using these tools in the context of their exercise, but whether students are then able to apply these skills to a more general context is still up for debate.

These tools are particularly distinctive through their relation the real world. Geospatial technologies can model the Earth and its processes well; by uniting traditionally disparate data sets, students begin to see connections between the various systems of the Earth. Furthermore, students can see a connection to real world applications of these programs through their work. Since the tasks they are provided are often not unlike those done by professionals, students can understand how what they are doing can be important in the professional world, imbuing their work with a sense of worth and practicality (Keiper 1999). Beyond helping prepare students for a job in the field of geospatial technologies, these activities also introduce students to technology more generally (Siegmund, Viehrig et al. 2007) as well as to the critical thinking that plays a vital role in almost every professional field (Bednarz 2004). For example, in some cases students actually gathered their own data to test their hypotheses, which helps students realize the entire scientific method and see how it works in practice (Kerski 2001). These systems, then, can connect students both to the Earth they live upon and those working upon this Earth.

Job skills are only one of many ways in which geospatial technologies can contribute in the long term to a student's success. For example, one study measuring students' self-efficacy and attitudes in using geospatial technologies found that those students using GIS improved their self-efficacy towards science and attitude toward technology more than the students who did the same activity with traditional methods (Baker and White 2003). Additionally, teaching students how to understand and use even simple computer mapping creates a more informed citizenry who comprehend interrelations and interdependence in our communities (Chandler and An 2007). Geospatial technologies may have the ability to contribute in many ways well beyond the one classroom experience for the students.

Author, Year	Age of students	Methodology	Results
Baker, and White, 2003	13-14	Compared results of pre- and post-tests for indicators of attitude and self-efficacy as well as in-class exercise for both students who used and did not use a GIS application.	-Use of GIS shown to significantly increase: o Students' self-efficacy towards science o Attitudes towards technology o Attitudes related to making personal decisions from scientific data o Attitudes towards analyzing and picturing scientific data in different ways -Students who used GIS did significantly better on the class exercises as graded by instructor.
Kerski, 2003; Wanner, and Kerski, 1999	14-18	Compared results of pre- and post-tests for general spatial analysis for both students who used and did not use a GIS application as well as looked at how well the students did on in-class exercises.	-General spatial analysis test scores either did not change or declined for students using a GIS. -Students using GIS scored significantly higher on in-class exercises than students doing the same exercises with traditional methods. -Students using GIS demonstrates a better ability to synthesize, identify, and describe reasons for human and physical patterns. -The use of GIS was shown to foster higher-order analytical and synthetic thinking and increase student knowledge of absolute and relative locations of places across the globe.
Linn, 1997	12-13	Compared results of pre- and post-tests for students both using and not using GIS in regards to their knowledge of the subject as well as a questionnaire.	-No significant difference in improvement between GIS or non-GIS users based on test scores. -Qualitative data indicated that students preferred using the computer programs to complete the activity, although they did not learn more about the subject from this program.
Meyer, Butterick et al., 1999	12-14	Compared results of a general location analysis between both students using and not using GIS for a classroom activity.	-Students using GIS performed more poorly than students not using GIS on the location analysis problem.
Patterson, Reeve et al., 2003	17-18	Compared results of a student learning outcome assessment between students who used GIS and those who did not.	-Test scores were significantly higher for students who used GIS. -In particular, students who used GIS did much better on drawing conclusions based on maps and making use of thematic maps.
West, 2003	14-18	Compared results of pre- and post-surveys for students who used GIS application on student's relationship to the subject matter and to technology.	-Use of GIS shown to: o Increase relevance of geographic study o Encourage more focused thought, motivation, and higher-level thinking skills o Improved students comfort with technology (although this could be attributed to just using computers, not the GIS) o Makes students feel less comfortable and less in control of their learning

Table 1: Summary of quantitative results looking at student learning with GIS.

What geospatial technologies can unequivocally contribute to is a building a student's sense of place, whether it's for their own community or another's. Some researchers contend that to attain transferable spatial thinking skills students need to look at an example in their own community so that the activity seems more relevant and important (Chandler and An 2007). However, by exploring and thinking critically about any specific place, students can feel that they know a locale intimately—in one example students from mainland USA followed researchers in Alaska and came to be familiar with certain towns and locations in rural Alaska (Doering and Veletsianos 2007). In most cases, however, the local place studied is where the students live (Bednarz 2004), and oftentimes the students are able to work with data provided to them by local government or other organizations. Students may even be able to add to this data with their own research and thereby contribute new knowledge to the community database. This service learning aspect enriches student learning experience since students are more likely to use their higher-order thinking skills when they can perceive the activity is highly relevant (West 2003). Frequently these local exercises culminate in presentations to the community about their findings where students can feel empowered as contributing members of society (Fitzpatrick 2001). Geospatial technologies can be at their most powerful and relevant for students when they are used within a local context.

Lastly, and perhaps most fundamentally, geospatial technologies can contribute to a student's experience by motivating them and by simply being fun to use. Even in studies where there was no difference in score between those who used a computer mapping application and those who did not, the teachers noted that the students using the technology seemed to be having more fun and enjoying the activity more (Linn 1997). Research has found that student thrive off of being in charge of what they are doing (Keiper 1999), which is frequently the case in the typically student-centered exercises using geospatial technologies (Audet and Paris 1997; Page 2003). Students also tend to be more engaged and focused when using GIS than in traditional classroom activities (Stewart, Schneiderman et al. 2001; West 2003). So despite the fact that scores may not always be significantly better for those students who use geospatial technologies, there are additional, less quantifiable, benefits to be considered when using these applications.

2.2 Summary of advantages and disadvantages

In summary, there are some notable advantages and disadvantages to using geospatial technologies as a tool in the classroom, which are reviewed in Table 2.

Advantages include that many schools already have the hardware that they need and that there are ways for teachers to find deals for less expensive software. Additionally, increasingly there are online resources offering lesson plans and free data for teachers interested in implementing geospatial technologies as a tool in their classroom. Teachers are also given the opportunity to use new teaching methods with this tool that may aid in attaining certain standards, teaching spatial/critical thinking, and imbuing their students with a sense of place. The variety of ways that geospatial technologies can be used is large, meaning that these tools are applicable in a number of teaching settings. Furthermore, students genuinely seem to enjoy using these tools and may acquire skills that will benefit them all their lives.

There are, however, obstacles to overcome when implementing geospatial technologies. If schools are not equipped properly or teachers don't know where to go for inexpensive resources, hardware, software, and data obtaining these can be extremely costly, as can a teacher's time when it comes to training and preparing lessons. Moreover, desktop GIS software in particular is far from intuitive and teachers and students may have a hard time learning even the basics. Teachers also have to be carefully to cater their teaching to the software; you cannot just use a geospatial technology and expect to reap the rewards, teachers need to learn how to teach effectively. Additionally, it is important to note that some quantitative studies have not shown a significant difference in improvement in general spatial skills for students using geospatial technologies against those who used traditional methods, suggesting that claims that geospatial technologies can help with critical and spatial thinking skills outside of the specific classroom activity better than other means may be unfounded.

For teachers thinking about implementing more traditional geospatial technologies in their classrooms, there are some clear costs and benefits that need to weighed. The next section will explore virtual globes, a new technology that may maintain the advantages cited here, while ameliorating some of the problems.

	Advantages	**Disadvantages**
Technology	-Schools may have hardware -Some software is free -Many different types of geospatial platforms for different needs -Some free data available	-Hardware/software can be expensive -Applications can be counter-intuitive and hard to learn -Desired data may be expensive
Support	-Support from administration and in technical operations is important	
Teachers and teaching	-Modernizes teaching methods to fit constructivist pedagogies -Caters to different learning styles -Encourages interdisciplinary thinking -May teach spatial thinking -Adheres to teaching standards -Can be used for most subjects in a variety of different ways -Teachers who have used geospatial technologies in their classroom are extremely enthusiastic about it	-Training can be costly, time-consuming, and may not always fully prepare teachers for implementing geospatial technologies in the best possible ways -Requires a pedagogical shift for some teachers -Attaining spatial thinking goals depends on the teachers understanding of these concepts -Some teaching standards may restrict the amount of time teachers have to implement geospatial technologies -The number of options for integration may be overwhelming for some teachers
Student experiences	-Activities tend to be very student-centered -May improve general critical thinking skills -May improve spatial thinking skills -Can easily understand real world applications of the software -May improve students attitudes and self-efficacy towards technology and the subject they are studying -Helps students develop a sense of place -Encourages connection to the local community -Learn how to use/interpret data -Fun and motivating	-Quantitative studies show that spatial thinking skills are not always attained (*see* Table 1) -May be distracting

Table 2: Summary of advantages and disadvantages of geospatial technologies.

2.3 Google Earth and virtual globes

As mentioned in Chapter 1, virtual globes were launched about halfway through the '00s, with Google Earth—the most widely used of these programs—first available in 2005. Google Earth has become immensely popular; as of February 2008, Google Earth has been downloaded over 350 million times around the world (Google 2008). This popularity is one of the reasons it was chosen as the geospatial tool to be used in this study. Therefore, it is worthwhile to explore what the advantages and disadvantages of Google Earth are relative to existing geospatial technologies.

2.3.1 Technology

While desktop GIS can require complicated hardware/software, outfitting a school to use Google Earth is much less expensive. Google Earth can work on any computer and almost any operating system—the only requirement to run Google Earth is a good Internet connection. The Internet today is available in 99% of American schools (Baker 2005), so even this condition is easily met by almost any classroom, although it does help if the connection is reliable and fast enough to display the imagery quickly. Additionally, unlike desktop GIS where licensing can be costly, the most basic licensing level of Google Earth (which includes the capabilities most sought after by classes) is free. Google Earth cuts down immensely on the costs of traditional desktop GIS and makes it inexpensive to outfit a classroom.

Another way in which Google Earth has an advantage over desktop GIS programs is through the ease of use of its application. The user interface is extremely simple with an elegant design that is intuitive for students and teachers. Instead of spending time having to learn the application both students and teachers can immediately pick up on how to use it and focus instead on the activity for which Google Earth is being used as a tool (Doering and Veletsianos 2007). This then cuts back on time further by reducing the need to train teachers on how to use the application so that any training can instead focus on how to effectively integrate Google Earth into the curriculum.

Not everyone sees this simplicity as advantageous, however. Google Earth lacks the analytical functions to make it a true GIS—it is better thought of as an interactive map. This may not be problematic, though, since most teachers using GIS rarely use the more sophisticated functions, employing the tool mainly for visualization so technologies such as Google Earth may actually suit their needs better (Baker 2005). However, researchers argue that, "this is the irony of GIS—if it were 'plug and play,' more teachers would use it, but much of the functionality and flexibility would have to be removed. This would make it less of a constructivist tool and more of a traditional one" (Kerski 2001 p. 83). Students may well learn no more through virtual globes than they would through other traditional mediums (Doering and Veletsianos 2007). Despite the truth in these statements, Google Earth is still a good way to introduce the concepts of more sophisticated GIS and in fact, it may act as a gateway to more analytical programs by opening the door for both students and teachers and showing them the tip of the iceberg of possibilities with geospatial technologies (Butler 2006; Kerski 2007; Patterson 2007; Kerski Unknown). In terms of analytical functions, Google Earth is limited, but depending on what the teacher hopes to accomplish by using this tool, it may not only not matter, but actually be beneficial that the interface is so simple.

In terms of data and data viewing, Google Earth also differs from traditional GIS. As mentioned, Google Earth is used primarily for visualization. Unlike most desktop GIS applications, Google Earth not only easily supports 3D viewing, but also has a huge variety of placemarks, topography, layers, and 3D buildings pre-loaded into the application students can 'walk' down streets, over mountains, or through ancient Rome and see a fairly accurate representation of what they would be able to see if they were really there. This, however, raises another issue with Google Earth: data quality. Other than the data pre-loaded into the application, there are a lot of free data for use in Google Earth through Google Earth Community (http://bbs.keyhole.com) as well as other sources. Unfortunately, the metadata for these sources are often limited. This is of course also a problem with desktop GIS, although teachers often use data provided by software companies or from reputable Internet sources. However Google Earth data—since it's so easy to create—often comes from non-professionals so while a tremendous amount of data may be freely available, its source may be questionable (Kerski 2007). In this case one of the boons of Google Earth, its popularity and ease of use, has also become a curse in some instances.

2.3.2 Support

Since Google Earth is so tied to the Internet, many resources are available on the web to help teachers and students. As mentioned, Google Earth Community (http://bbs.keyhole.com) provides a variety of forums for people to ask questions, post data, and upload lesson plans—this site also has the advantage of having both a moderated and un-moderated section so that users can have a sense of whether their information is coming from a reputable source. Furthermore, both on this site and on others (*see* www.google. com/educators *and* classroomgoogleearth.wikispaces. com/), there are a number of examples of how Google Earth has been used in the classroom including exact lesson plans for teachers. Furthermore, these sites provide a platform for students to easily share and collaborate on the work they do (Butler 2006)—a model that proved successful in at least one case study where students in their classroom collaborated with scientists in the Arctic to map their progression as they traveled through Alaska (Doering and Veletsianos 2007). Support for Google Earth usage on the Internet abounds, both in terms of technical help and in terms of lesson plans, with teachers and students able to easily access reputable sources and reach out to others using in this tool.

2.3.3 Teachers and teaching

Virtual globes can be appealing to teachers for a number of reasons. Firstly, as mentioned, the interface is extremely intuitive so teachers do not have to worry themselves about intense training or with the technicality of the software—they can focus more on teaching *with* the tool and less on teaching *about* it (Baker 2005). Researchers say that tools like Google Earth can still cater to teaching standards despite having less advanced functionality (Patterson 2007) but that some of the other advantages may be lost. Interactive maps such as Google Earth are not a GIS since they have no analytical capabilities suggesting that this tool may not stress spatial thinking or geographical skill as much (Meyer, Butterick et al. 1999). So for teachers, while Google Earth is much easier to implement than desktop GIS, Google Earth's ability to teach spatial thinking is questionable, a topic which will be examined in depth in the following chapters.

2.3.4 Student experiences

Feedback from students who have used Google Earth has been extremely positive. Students love how dynamic the interface can be (Kerski 2007) and have a lot of fun using it. In fact, in one study that made use of both Google Earth and ArcExplorer Java Education for Educators (AEJEE), students preferred Google Earth to AEJEE citing that it was more fun (Doering and Veletsianos 2007). This entertainment aspect can have its consequences, however, as students may find the tool distracting to the point that teachers have a hard time controlling their classes and students have difficulty staying on task (Kerski 2007). With Google Earth students also have the advantage that this application is downloadable on practically any computer, meaning once they know how to use Google Earth, they can easily use this tool at home for research and projects. So while students may not necessarily be getting the same time of inquiry-based learning with Google Earth as with applications with analytical tools, there is still merit in engaging students and reinvigorating their learning with an easy to use and captivating tool.

2.4 Conclusions

The use of geospatial technologies in the classroom has developed a rich history since the early 1990s with conferences, research, and many success stories to be had. Research looking at the use of more traditional geospatial technologies has found some striking advantages and disadvantages. The recent addition of virtual globes to the field has opened up exciting new doors since this tool manages to mitigate some of the problems of using desktop GIS as a teaching tool such a training time and cost. Since the simplicity of these interfaces means that more advanced analytical functions have been cut out, there has been some doubt as to whether virtual globes can be used to achieve the same learning objectives as a GIS and therefore maintain these advantages. This study looks at this question in depth by using Google Earth in a classroom to quantify the differences in learning between students who use Google Earth and those who use paper maps for a spatial analysis class exercise.

3 Methodology

The objective of this study is to attempt to quantify students' learning experience with Google Earth, looking in this case at the use of Google Earth to teach spatial thinking. The results will attend to several pre-determined hypotheses:

- H_1: Scores for exercise 1 and 2 separately are the same for both techniques
- H_2: Students demonstrate the same learning methods for paper maps and Google Earth
- H_3: Previous exposure to maps and geographic technologies will not affect score on either exercise

The hope is that Google Earth will be shown to overcome some of the traditional obstacles of desktop GIS, while maintaining the benefits. To try to attain this goal, this study looks at a group of 70 sixth grade students (age 11-12) in their language arts class. This class was chosen because the teacher was interested in having her class use this technology, even though the teacher had no previous exposure to Google Earth.

Every effort was made to figure out an appropriate way to integrate a Google Earth activity into the teacher's pre-existing curriculum. Throughout this year these students will be communicating with a woman from the community who is living in Ghana as a part of the American Peace Corps program writing to her to ask her about her life in this country. Before the students started corresponding with this woman the teacher wanted to run a class to introduce the students to the country so that they had some background. It was decided that this would be an excellent opportunity to fluidly integrated Google Earth into the lesson by using it as a tool to introduce the country of Ghana to the students.

3.1 Outline of exercises and feedback retrieval

After some brainstorming of an interesting activity it was decided that there would be two main exercises for the students to work on during the class and that the students would fill out a worksheet reflecting their work on these two exercises. Since there were four classes during the day of 15-20 students, it was determined that two of the classes would do this activity with paper maps and the other two would do the same activity with Google Earth, a structure that allows for the comparison of results between the two teaching methods. Since it was thought that students' previous exposure to maps and geographic technology might affect their results, the day after the activity students filled out a questionnaire in regards to their experience with paper maps, online maps, GIS, virtual globes, and GPS.

3.1.1 Pre- and post-exercise activities

Rather than just throwing students into the exercises, students in all four classes spent about 10-15 minutes discussing Ghana before launching into the activity. Students were asked what they knew about Ghana already and how big they thought the area and population of Ghana is relative to the state that they are from, as well as what they thought the language and capital of Ghana might be. At this point the students were shown an outline map of the country and asked what they thought the geography of the country might be like. Finally, since the first exercise involves thinking critically about where to place the capital, students were asked to offer suggestions of what was good and what was bad about where the current capital, Accra, is located. From this brief introduction, the students in all four classes had the two exercises explained to them and we set off on their own in pairs. Students were also encouraged to ask questions while doing the two exercises if they did not understand any terminology.

For the two classes using Google Earth, a brief introduction to the application was given. As the interface is so intuitive, this did not have to be a particularly long introduction. The students were taught how to open the KML file they would be using, expand the layers so that they could see the different overlays and read information in the placemarks. No real introduction to navigation was necessary since the students all understood immediately how to get around in the program. The students were also provided with an instructional sheet on some of the basic functions of Google Earth that they could refer to if they needed help (see Appendix 5). This ensured that the students were not just spending their class time learning the technology, but actually learning the subject matter (Doering and Veletsianos 2007). The decision to limit the explanation of the interface was deliberate to stress that Google Earth manages to overcome the obstacles of traditional desktop GIS by providing an intuitive interface that does not require intensive training.

During the exercise itself both the teacher and the researcher walked around the classroom to talk to the students and clarify any questions either related to the content of the activity or to the Google Earth application.

After completing the exercises described in the next two sections, rather than just dismissing the students the last fives minutes of class was used to debrief the activity. Since most students were able to complete the first exercise, they were asked to come up to the front of the room to show on a map where they had chose to put the capital of Ghana and to give a brief explanation of their choice. This provided a way for the students to verbally think through their responses and communicate their choices to their classmates.

3.1.2 Exercise 1

The first exercise (see Appendix 1) was meant to test the students' ability to reason spatially. The students were given thirteen maps showing different variables of Ghana such as political divisions, drainage, erosion, annual rainfall, mining deposits, health of children, as well as others (see Appendix 2). The students in the two classes using paper maps were given color copies of these maps in a packet while the students using Google Earth had these thirteen maps as overlays in the program.

The students were provided the following introduction to the first exercise, followed by a blank outline map of Ghana where they could indicate their new chosen location; text in parentheses separated by a slash indicates the difference in text between that given to the students using Google Earth and that given to the students using paper maps:

> The first European country to explore Ghana was Portugal in the 1400's (the same time Columbus was sailing to America!). Soon after, other countries from Europe, such as the Netherlands, Sweden, England, and Denmark, decided to send people from their countries to the region as well, mainly so that they could try to claim the land as well as any gold or other treasures they found there.
>
> Because at the time the best way to get to Ghana was by sea, Accra became the capital since it was right on the ocean. Pretend you are a modern day explorer who has to decide where to place a new capital in Ghana—where would you put it?
>
> Using the (packet of maps)/(overlays of maps) showing information about Ghana, think about what is important to consider when placing a capital. Should it be near the center of the country or on a coast? Near the gold mines or far away? Do you need to be near roads or can you be in the country? Draw a star on the map below where you think you would site the capital today.

On the following page students were asked to give a short explanation of why they chose to put the capital there, list the maps they used to reach this decision in order of importance, and indicate what other maps they might find valuable for determining where to locate the capital.

To quantify this exercise, both the answers of the student as well as which maps the students factored in their activity were used. Scores for how well the students did on answering the question were established from a pre-determined scoring rubric (see Table 3). Students could be given half scores (i.e. 2.5, 3.5, etc) if it was felt that their results fell between two categories. Exercises 1—and Exercise 2—were graded without knowing whether this student had used paper maps or Google Earth until after scoring so as not to sway the results.

The methodology for this exercise was largely based upon Kerksi and Wanner from 1999 who used a similar methodology—having students locate the ideal location for a new restaurant franchise based on maps of several different variables—in their quantification of student learning using desktop GIS. The scoring rubric presented in Table 3 was also adapted from the one presented in their paper.

	Score: 1	Score: 2	Score: 3	Score: 4	Score: 5
Number of maps used	None	One	Two	Three	Four or more
Attention to Detail	No detail	Some detail; one sentence	Two meaningful sentences	Three meaningful sentences	Four or more meaningful sentences
Clarity	Incoherent	Some explanation; hard to understand	Adequate explanation	Thorough explanations	Excellent clarity and use of logic
Spatial Thinking	None	Some spatial thinking even if errors	Some spatial thinking; no errors	Explains at least one spatial relationship	Explains multiple spatial relationships
Other information	None	Offers one suggestion, even if problematic	Offers one good suggestion	Offers two suggestions	Offers three or more suggestions

Table 3: Scoring rubric for exercise 1, adapted from Kerski and Wanner, 1999.

3.1.3 Exercise 2

The basic idea behind this second activity was to have students in these four classes read six letters from 'students' in different parts of Ghana (the letters were actually written by the researcher) that contained clues about where the Ghanaian students lived and match them with six possible locations based on written information about the places as well as the maps from the first exercise. While the first exercise sought specifically to look at how well students reasoned spatially, the second exercise aimed to determine the differences between student using paper maps and Google Earth in the sources they used to complete the exercise.

The students were provided with written descriptions of the six places that, for the students using paper maps, meant that they had a packet of information (see Appendix 3), while the students using Google Earth had this information in six placemarks (see Figure 2) students could click on these placemarks to read about each of the places; an example of an expanded placemark can be seen in Figure 3. To determine whether students were more likely to use map sources or text sources, students were asked to circle the clues in the letters that helped them decide which place that Ghanaian student was from. The students' instructions were as follows; again, text in parentheses separated by a slash indicates the difference in text between that given to the students using Google Earth and that given to the students using paper maps:

Much like the creation of the United States brought together many tribes of Native Americans and different European people, the country of Ghana unites several different native groups/languages. Begin by reading the descriptions of the six different locations in the (second half of the packet)/(placemarks). Although today Ghana's people are fairly heterogeneous, or mixed, different places in the country are still culturally, geographically, and economically different from one another. Below are several letters from school children in Ghana; read them and using clues from their daily lives, compare that information with what you can learn about each place or what you can see in the maps used in Exercise 1. Fill in the blank with where they are from and circle which clue helped you the most for deciding where they are from.

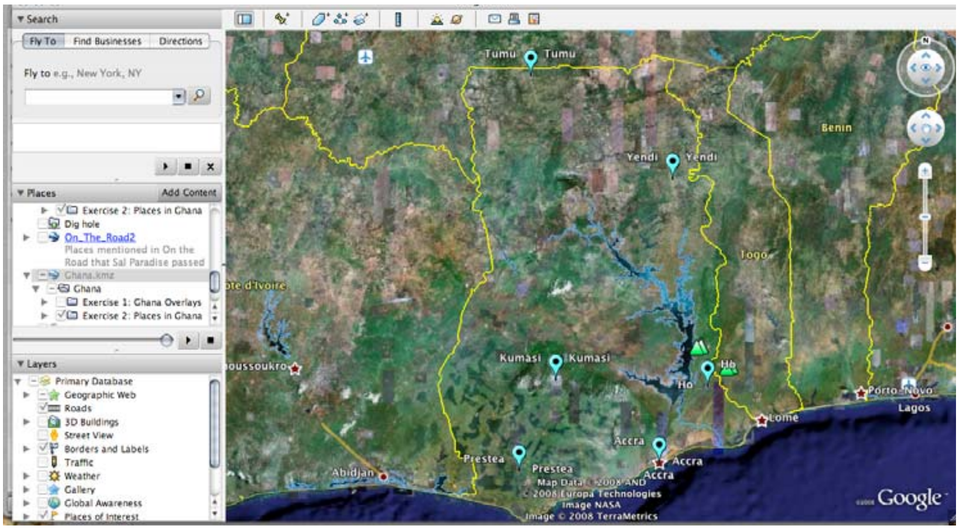


Figure 2: Google Earth with six locations in Ghana (Tumu, Yendi, Ho, Accra, Kumasi, and Prestea) indicated by placemark.

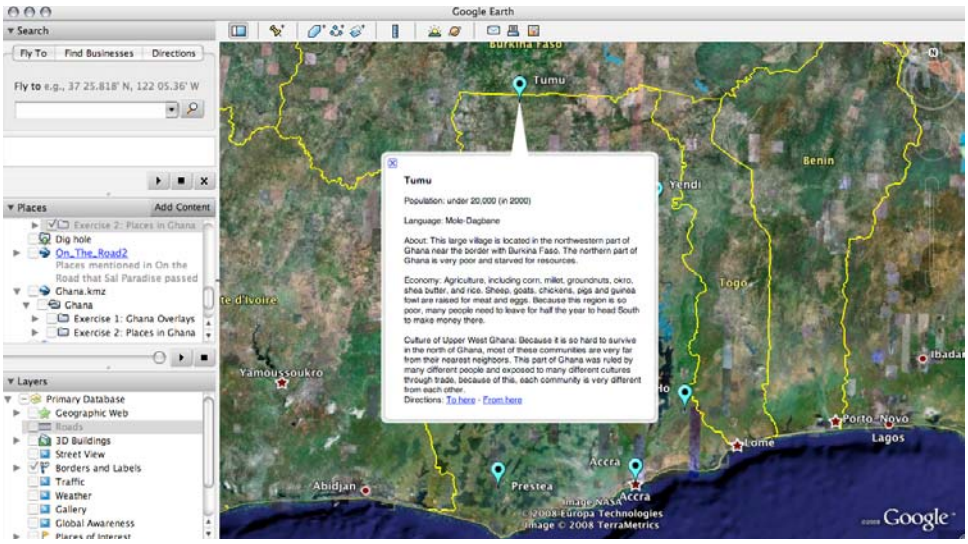


Figure 3: Placemark for Tumu with information about this location.

The second exercise was more easily quantifiable than the first exercise since it was possible to count how many matches were correctly made on each worksheet. Scores therefore were based on the percentage of correct matches the students made. Whether the students used clues from the text or from the maps was not factored into the score since this difference did not change the level of success—students could have successfully completely this second exercise using information from either the text or maps. The differences in text-versus map-based clues was instead used to analyze the differences between students who used paper maps and Google Earth in which sources they used for clues; the percentage of clues from each source was employed to measure this variation. It should be noted that students were encouraged, when feeling short on time, to concentrate on providing a thorough answer for the first exercise rather than trying to finish everything so only about half of the class was able to do both the first and the second exercises.

3.1.4 Questionnaire

Since the students' previous exposure to geospatial technologies might affect how well they did on these activities, students were asked to fill out a brief questionnaire about their use of both paper and electronic maps (see Appendix 4). Due to the limited amount of time in class on the day of the exercises, the teacher was left with the questionnaires for the students to fill out the following day. This also meant that the researcher was not present when the students filled them in, hopefully indicating that the responses elicited were more honest. The students who worked with paper maps were only given the first section of the questionnaire where they indicated how often they used paper maps, online maps like Google Maps, GIS, GPS, and virtual globes such as Google Earth. Students who had worked with Google Earth were also asked to disclose what they liked about the application, what they did not like, and whether they would like/be likely to use it again either in class or at home.

3.1.5 Teacher feedback

To get an opinion from another point of view, casual feedback from the teacher was requested as well. About one week after the activity the teacher was emailed asking for her perceptions of how the day went with a series of suggested questions for discussion. This response will be considered in the discussion of Chapter 4.

3.2 Considerations for the exercises

3.2.1 Placing the exercises in context

These exercises were developed with the aim that their structure would allow this research to determine the differences in learning between students using traditional methods and Google Earth. This study hopes to also establish whether Google Earth can easily be implemented in classrooms, thereby overcoming some of the obstacles of using desktop GIS as a teaching tool.

These exercises seek to be consistent with characteristics of geospatial technology implementation shown to be important in other studies. Firstly, this activity exemplifies how

Google Earth can be fluidly integrated into the existing curriculum. There was no need to create a whole new activity just to use Google Earth; it was simply a matter of realizing that Google Earth could be an effective way for students to explore the country of Ghana. Furthermore, this activity is an example of how Google Earth can facilitate the understanding of interdisciplinary connections: this is a language arts class but this activity is asking students to answer geographical questions by looking at geologic, demographic, and topographic data (among others). Although not measured in this study, this type of exercise—where students are looking in depth at a few places—may also fit into the idea of geospatial technologies as a tool for fostering sense of place presented in Section 2.2.4. Importantly, it was a conscious decision to only work with the students for one day since this is the most frequent way that teachers choose to implement geospatial technologies (Kerski 2003) even though this is not necessarily the best suggested way of implementing; hopefully this analysis will help determine whether this level of integration is effective for achieving the goals a teacher is hoping to attain by using this technology in their classroom. In these ways, this activity seeks to reflect some of the suggestions and/or precedents of previous research for implementation.

Critics of Google Earth and simpler geospatial technology may find fault in the design of this activity. Unfortunately, in order to have a control group, the exercises had to be designed so that they could be done both with paper maps and Google Earth meaning that the features that make Google Earth unique are by necessity not being utilized, a problem also encountered in other similar research (Linn 1997). Researchers argue that when you use technology to simply change the way you teach, rather than adding value to the subject, you are not going to realize the full potential of the tool (Linn 1997; Chandler and An 2007). One could argue, however, that value may be added in another way, by introducing the students to a new technology. Regardless, using more sophisticated features of Google Earth had to be sacrificed in this case to maintain the integrity of this study.

Additionally, this study sought to make use of the work of previous research to inform this case study. As mentioned, the methodology of the first exercise was largely based upon a previous quantitative study using desktop GIS with high school students (Wanner and Kerski 1999). The exercise in this 1999 paper, as well as the one in this study, rely heavily on map overlay and a student's ability to understand this concept. At least one study looking at the map overlay concept found a significant difference in the comprehension of this concept between middle school and high school students; middle school students were not only significantly less likely to use map overlay to answer a question that this technique would befit, but only half of these younger students actually used it correctly (Battersby, Golledge et al. 2006). Spatial reasoning is a skill that develops with age but quantitative and qualitative evidence from the activity seems to suggest that the students did understand the concept and were able to make use of it.

This study attempts to adhere to suggestions for the best implementation methods, but some compromise was necessary since the design of this study necessitated a control group.

3.2.2 Factors of influence

As a part of the methodology it is important to review other specifics of the activity that may need to be considered by summarizing the demographics of the school and community as well as looking at the conditions of the study.

The school at which this research was done is located in the northeastern part of the United States in a small city with a population around 20,000. This city is 98% Caucasian, a statistic reflected in the population of the schools (US Census Bureau 2000a). In this city the median household income in 2000 was $58,557, which is quite a bit higher than the national average of $41,994 (US Census Bureau 2000b). The school at which this activity took place is a public school within the city that serves three years of students with 687 students for 32 classrooms, averaging around 20 students per classroom (Superintendent's Report 2007). Due to student absences and other factors, this activity reached 70 students in four classes. Out of these students, 30 students were male and 37 female.

This activity was done at the end of September, meaning that the students had just started their new grade and new school a few weeks before. The students in the four classes taking part in this experiment are all enrolled in the same course of study and have been so they are coming from the same educational background. It was decided that the first two classes of the day would do the exercise with paper maps while the two classes in the afternoon would use Google Earth; this ensures that students in the morning would not tell their friends about what they did on the computers, only to deny the students in the afternoon exposure to this technology. Class periods in this school run for one hour so each of the four classes had one hour to complete the activity meaning that the students using Google Earth had slightly less time to work on the activity since five minutes were spent acquainting them with the application. For the activity, students paired themselves randomly so that the students would have someone else to talk to about their ideas. Only one worksheet was submitted per pair although the questionnaires were filled out individually. This means that there are some problems with comparing the results of the questionnaire to that of the exercise since the worksheet represents two students' combined thinking. Since the researcher was unfamiliar with any of the students in the class and at no point asked for their names, it was determined that actual names of the students could be used on both the worksheet and the questionnaire in order to match them for analysis.

The students using paper maps did the activity in their regular classroom while the students using Google Earth did the activity in a lab where the computers were in a U-shaped formation with a projector screen hooked up to one of the computers at the front. All machines were PCs running Windows software. The computer department at the school loaded Google Earth onto these machines and put the necessary KML files onto the server where the students could access them.

3.3 Summary

This exercise was designed to try to look at the differences in learning between students who use paper maps and those who use Google Earth by having four classes of sixth grade students do two exercises to introduce themselves to the country of Ghana. The design of this study was informed heavily by previous research in this field. This research also sought to take into consideration suggestions of other authors for how best to effectively implement geospatial technologies with the two notable exceptions of not utilizing advanced features (necessary to have a control group) and having this be just a one day activity (done because most teachers in the past have used these platforms thusly). It is hoped that this research will be able to inform teachers for how best to effectively implement Google Earth in their classroom. A summary of the activity outline is presented in Figure 4.

Goal of activity: Provide an introduction for the students to the country of Ghana while simultaneously challenging them to think spatially.

Hypotheses:

- **H_1:** Scores for exercise 1 and 2 separately are the same for both techniques
- **H_2:** Students demonstrate the same learning methods for paper maps and Google Earth
- **H_3:** Previous exposure to maps and geographic technologies will not affect score on either exercise

Student activities:

- **Exercise 1:** Students look at thirteen different maps for the country of Ghana and must suggest their ideal location for the capital based on the information provided in those maps. Students are asked to defend their choice and list the maps that factored into their decision in order of importance. Scoring is based on a pre-determined rubric (*see* Table 3).
- **Exercise 2:** Students are provided with descriptions of six different places in the country of Ghana and asked to read letters from students in each of those six places to try to match the letter with the location. Additionally, students are asked to circle which keywords in the letters helped determine the location so as to determine a trend in students using either text- or map-based clues. Scoring is based on the percent of correct matches.
- **Questionnaire:** Students fill out a questionnaire the day after their activity indicating their previous exposure to various forms of geospatial technologies. Students who used a virtual globe to complete the activity were additionally asked to provide quantitative feedback as to what the liked/didn't like about using the software and whether they would like to use it again.

Classroom logistics:

- **Length of activity:** One class period, which is one hour in length.
- **Student pairs:** Students completed this activity in pairs that were self-selected. This resulted in 16 pairs completing the exercises with paper maps and 19 pairs completing the exercise with Google Earth.
- **Organization of classes:** The first two classes of the day, meeting before lunch, completed the exercise with paper maps. The last two classes of the day, meeting after lunch, completed the exercise with Google Earth.

Figure 4: Summary of activity.

4 Results

This section will overview the results of this activity and the statistical methods that contributed to these findings. The ramifications and significance of these results will be discussed in Chapter 5. This chapter will refer only to the summary statistics of the data, but a full list of the data sets used in these calculations are presented in Appendix 6.

4.1 Exercise 1 results

The first exercise asked the students to look at a number of maps of Ghana, either as layers in Google Earth or as paper maps, to determine where they would locate the capital based upon these variables. The students were asked to defend their results in a brief statement as well as list which maps (and therefore variables) factored into their decision, in order of importance. The results for this first exercise are dependent on a score given to each pair of students based on a pre-determined scoring rubric, as presented in Table 3.

Since the students were working in pairs the sample size is greatly reduced from the initial seventy students. After the exercise was run there were sixteen worksheets (from sixteen groups) of students who used paper maps and nineteen worksheets (from nineteen groups) for students who used Google Earth to do this activity. Students who used paper maps to complete the activity had a slightly higher average score on Exercise 1 than those who used Google Earth; the average score for paper maps was 3.56 while for Google Earth the score was 3.03, as can be seen in Table 4. A simple two-tail t-test comparing the results of these scores finds that p for this data set is .14 with α as .05, meaning that the difference in the means of the scores is not statistically significant. Looking back at the initial hypotheses laid out for this experiment, this lack of significance means that we have no evidence to reject the null hypothesis that the scores are the same for these two methods of learning.

	Paper Maps	Google Earth
n	16	19
Mean	3.56	3.03
Standard Dev.	1.03	1.07

Table 4: Results for score of Exercise 1.

The second part of this first exercise asked the students to list the maps that contributed to their decision of where to locate the capital of Ghana, in order of importance. Table 5 presents the content of the thirteen maps that the students were provided. The map number refers to their number as they are referenced in the figures in this chapter and the order indicates the sequence in which they were presented to the student. Quantifying which maps the students used in their decision allows us to see whether students approached the problem differently with each method.

Map Topic	Map Number	Order with paper maps	Order with Google Earth
Topographic and Base map	1	1	1
Elevation	2	2	2
Annual Rainfall	3	3	10
Annual Temperature	4	4	11
River Systems	5	5	12
Erosion	6	6	13
Gold mine locations	7	7	5
Transportation and National Parks	8	8	4
Land cover	9	9	6
Population Density	10	10	7
Percent of children underweight	11	11	9
Percent of people living in poverty	12	12	8
Language	13	13	3

Table 5: Map topics, numbers, and orders for each of the two methods.

Before seeking to answer this question, though, it is also interesting to look generally at which maps the students chose to use with either method. Figure 5 presents a chart of which maps the students cited as having used in their decision. Since the students could list as many of the thirteen maps as they wanted, the gray bars on the chart look at the maps the students chose to use including all that they listed, while the black bars show just the top four maps that students thought were the most important. To determine whether there is a pattern in these choices, a x^2 test was used. This test shows no pattern when looking at all the maps the students said they used (the gray bars), with p=.14, but some pattern in the observed versus expected values for the students top four choices (the black bars), with p<.01. This indicates that there is in fact a pattern in the students' top four choices of maps in their decision. These results are also reflected in looking at map choice for the students using either paper maps or Google Earth. Again with either of these methods, there is no pattern when looking overall at all the maps the students listed (p=.075 for paper maps and p=.233 for Google Earth), but for each of these methods, there is a pattern indicated in their top four choices with p<.01 for paper maps and p<.02 for Google Earth. In summary, looking individually at either the overall choices, the choices for paper maps, or the choices for Google Earth, it can be seen that there is no pattern when you include all the maps the students said they used in their decision, but there is a pattern when looking at just the top four map choices for each of these three groups.

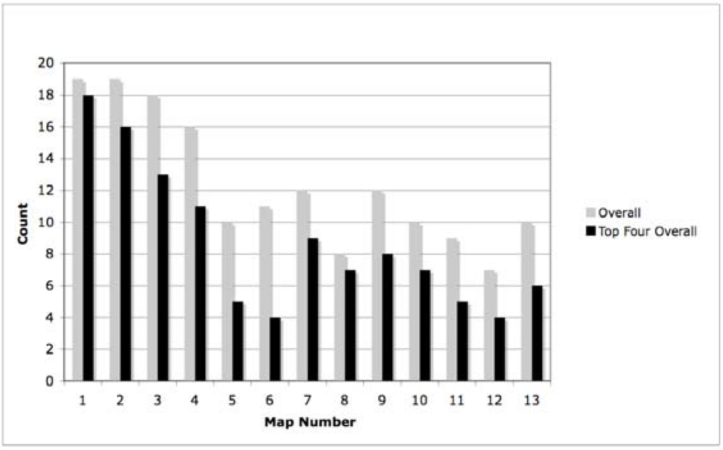


Figure 5: Maps used for analysis by both students using paper maps and Google Earth.

While this analysis is interesting, it is far more informative for the sake of this study to look at the comparison of the maps used by those students using paper maps versus those using Google Earth. Again, using the x^2 test to look at the differences between these two methods reveals no significant pattern when looking at all the maps the student listed (p=.067) but a significant difference in choice with p<.01when looking at a comparison of the top four map choices, as seen in Figure 6. This indicates that students are approaching the way they answer this question differently using the two methods.

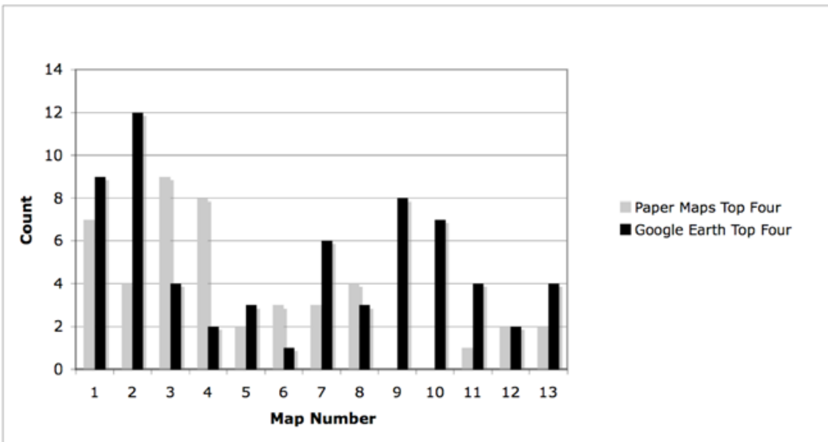


Figure 6: Difference in top four map choices for two methods.

It should be noted that these maps were unintentionally presented to the students using paper maps and Google Earth in a different order. It could be then, that the order in which the maps were presented to the students is the variable affecting the difference in map choice. However, when you rearrange the chart to show on the x-axis the order in which the maps were presented to the students, it is clear that the sequence of maps with each of the two methods effected which maps the students used in each group differently, as presented in Figure 7.

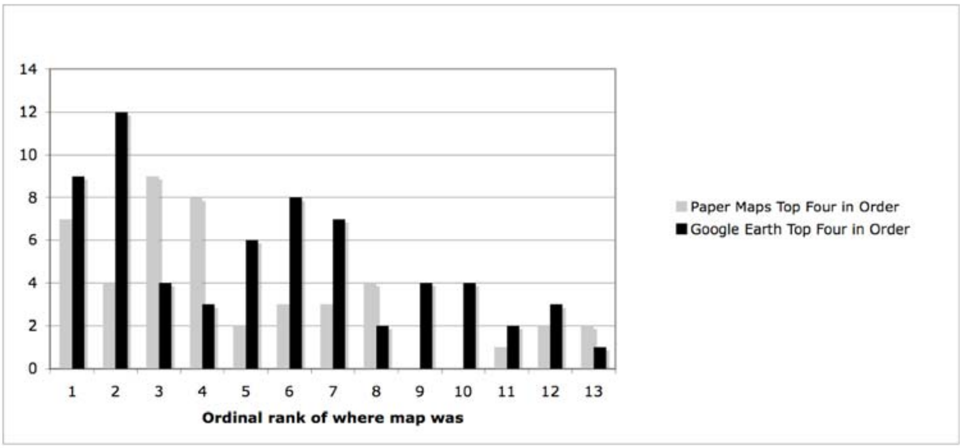


Figure 7: Top four maps used by students for analysis in order maps were presented to the students.

4.2 Exercise 2 results

The second exercise asked the students to look either at placemarks or descriptions of places as well as the maps from the first exercise to try to match six locations in Ghana with letters of six Ghanaian students that include clues to where they live. Scores for this part are based on the percentage of the six total matches that the students got correct. Additionally, students were asked to circle the clue(s) that they used to decide where that Ghanaian student was from to determine whether students were drawing these clues primarily from text or from maps.

Because students were asked to make sure they did a thorough job on the first exercise before moving on to the second exercise, the sample size for this second exercise is much smaller with n=9 for paper maps and n=15 for Google Earth. It is worth noting for the discussion in Chapter 5 that more students using Google Earth were able to complete both exercises. The differences in mean and standard deviation for the percentage correct of the two methods are presented in Table 3. Again, the average is slightly higher for the students who completed this exercise with paper maps than for those who used Google Earth. However, using the same two-tail t-test for this data set again reveals that the difference in mean is not significant, with p=.08 for an α of .05. Exercise 2 therefore also supports the first hypothesis that there is no difference in score between the two methods.

	Paper Maps	Google Earth
n	9	15
Mean	0.96	0.78
Standard Dev.	0.11	0.35

Table 6: Results for score for Exercise 2.

The second part of this analysis is to compare the percentage of clues students used to match the cities to letters from either map or text sources with each method. Again, since time was an issue, the sample size of students who actually went through and indicated the clues that they used drops further for this statistic. Table 7 presents the summary statistics for the differences between the two methods. Once more the mean percentage of map-based clues used to make the match is higher for the students who completed this activity using paper maps than for those who used Google Earth. Not surprisingly, since the sample size is so small and the standard deviation so great, the two-tail t-test shows no significance in the difference of means with p=.53. Unlike with the first exercise where there did seem to be a significant difference in the approach taken by students in regards to which maps they used in their decision, the evidence here suggests that there is no difference—or at least that there is not enough data to determine a difference—between the approaches taken by students using each method to complete this activity.

	Paper Maps	Google Earth
n	5	5
Mean	0.49	0.40
Standard Dev.	0.22	0.25

Table 7: Difference in percentage of map-based clues for two methods.

4.3 Questionnaire results

Both the students doing the exercise with paper maps as well as the students doing the exercise with Google Earth had a questionnaire to fill out the day after their exercise. The students who used Google Earth, however, had an additional section of the questionnaire asking specifically for their feedback on what they thought of using Google Earth. The goal of this questionnaire was to elicit feedback on the activity for the Google Earth students and in general to determine whether previous exposure to maps and geographic technology affected the results of the students. Students were asked to respond to this questionnaire not including the work they had done the previous day for this activity.

Although not directly one of the goals of the questionnaire, the overall results indicating how often students use geographic information are interesting. Figure 8 shows the results of this survey grouped by frequency. It seems that while many students have never heard of or used a GIS, 71% of the students (n=66) had experience with virtual globes and that 34% use virtual globes more than once a month. Also notable is the fact that 30% (n=66) use GPS devices and 41% (n=68) use online maps more than once a month. These students clearly have had quite a bit of exposure to geographic technology.

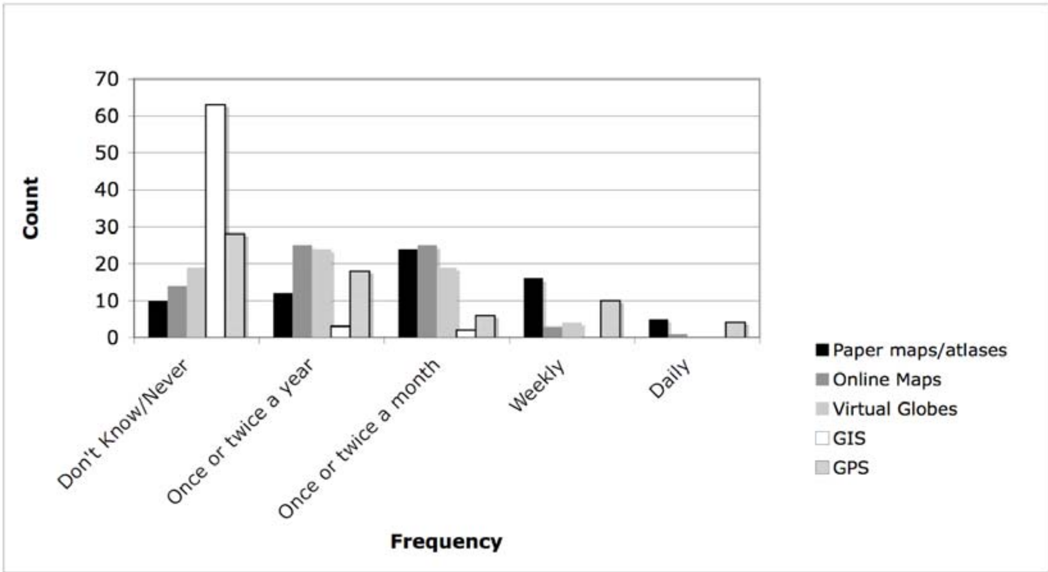


Figure 8: Students' exposure to geographic information prior to activity.

The third set of hypotheses presented in the first chapter attends to whether this exposure to technology affects how they perform on the exercises. This is somewhat problematic since the students did this activity in pairs—it is possible and even likely that students with different levels of exposure would be paired for this activity. In fact, the mean correlation between paired students in regards to their experience was .4, with a standard deviation of .35 indicating that some groups were paired well in terms of experience while others came from very different backgrounds. ANOVA (analysis of variance) was used to determine whether exposure to any of these technologies correlated with the scores obtained on Exercise 1 or Exercise 2. In every case there is no significant correlation between scores from either exercise to the students' exposure to geographic technologies in any of the five categories. This analysis not only compared the results of the exercise to all five levels of exposure but also to exposure in a binary sense, in terms of students either having ever used that geographic information or not. None of these comparisons resulted in any significant correlation. Perhaps the most notable of these comparisons is that fact that experience with Google Earth had no significant correlation with how well students using Google Earth scored on their activity. Again, calculating this statistic is tricky from the very beginning since the students completed the activity in random pairs, but it seems that previous exposure to these technologies had no influence on well they scored.

The second part of the questionnaire was given only to students who used Google Earth and asked for more qualitative feedback on what they thought of the application. Students were first asked to indicate what they liked about using the program; many students mentioned the ability to zoom and explore as they liked and used words such as "cool," "fun," and "interesting" to describe the program. Several students went into more depth with their response: "I enjoyed working with Google Earth because I love looking at all of the little details of different places" and "Yes [I enjoyed working with Google Earth] because it was fun to see difference places. And finding *anywhere* on Earth. Even your house [*sic*]" [emphasis in original]. Two students even enthusiastically announced they were going to go home and download it on their home computers. Students were also asked to state anything they didn't like and while many students wrote "nothing!" several commented that they found it confusing, "blurry," that the computer was too slow, and that it was "sometimes hard to understand." The students were then asked whether they would be likely to use this application at home for fun or for research and if they would like to use it again in class. As can be seen in Figure 9, more than three-quarters, 77% with n=36, stated that they would want to use Google Earth again at home. This enthusiasm for the technology is reflected in Figure 10 as well, where 92% of the students resoundingly indicated that they would like to use Google Earth again in school. It should be noted that an ANOVA test shows a significant statistical relationship between how students answered the question represented in Figure 10 and how well they scored on the exercises with $p<.01$ for the score on Exercise 1 and $p<.02$ for the score on Exercise 2. Clearly the students overall enjoyed the experience of using Google Earth, although there seem to have been some frustration with the processing speed of the computers and the Internet connection as well as with the application.

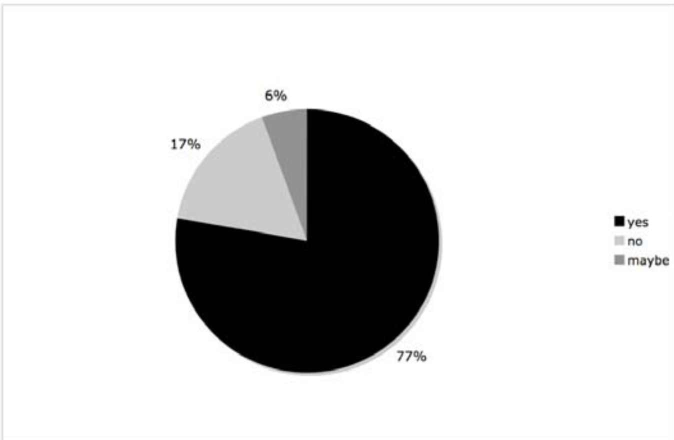


Figure 9: Student response to their interest in using Google Earth again at home.

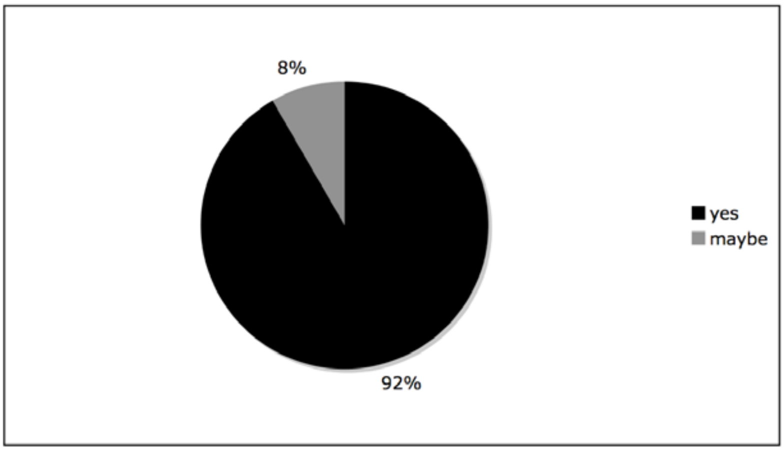


Figure 10: Student response to their interest in using Google Earth again in class.

4.3 Gender

It is important to consider the role of gender in spatial skills studies. Research has shown that even from an early age sex differences can be seen between males and females; it has been hypothesized that these differences are a result of nurture, nature, and of the interaction of the two (Downs and DeSouza 2006). Unfortunately, as with the questionnaire, it is difficult to consider gender in the case of this study because the activity was done in pairs, some of which were single sex and some of which were mixed. It is worth noting that since the pairs were largely self-selected, at this age group this resulted in a number of single-sex pairings. Regardless of this problem, ANOVA tests were run by sex for score on either of exercises as well as for sex by learning method. None of these tests resulted in any significance.

4.4 Results summary

To help summarize the results presented in this chapter, **Error! Reference source not found.** shows the outcome of this study in relation to Exercise 1, Exercise 2, and the Questionnaire. The colored boxes show a statistical result with the light boxes indicating a non-significant result ('NS') and the darker boxes with a darker border showing a statistically significant result.

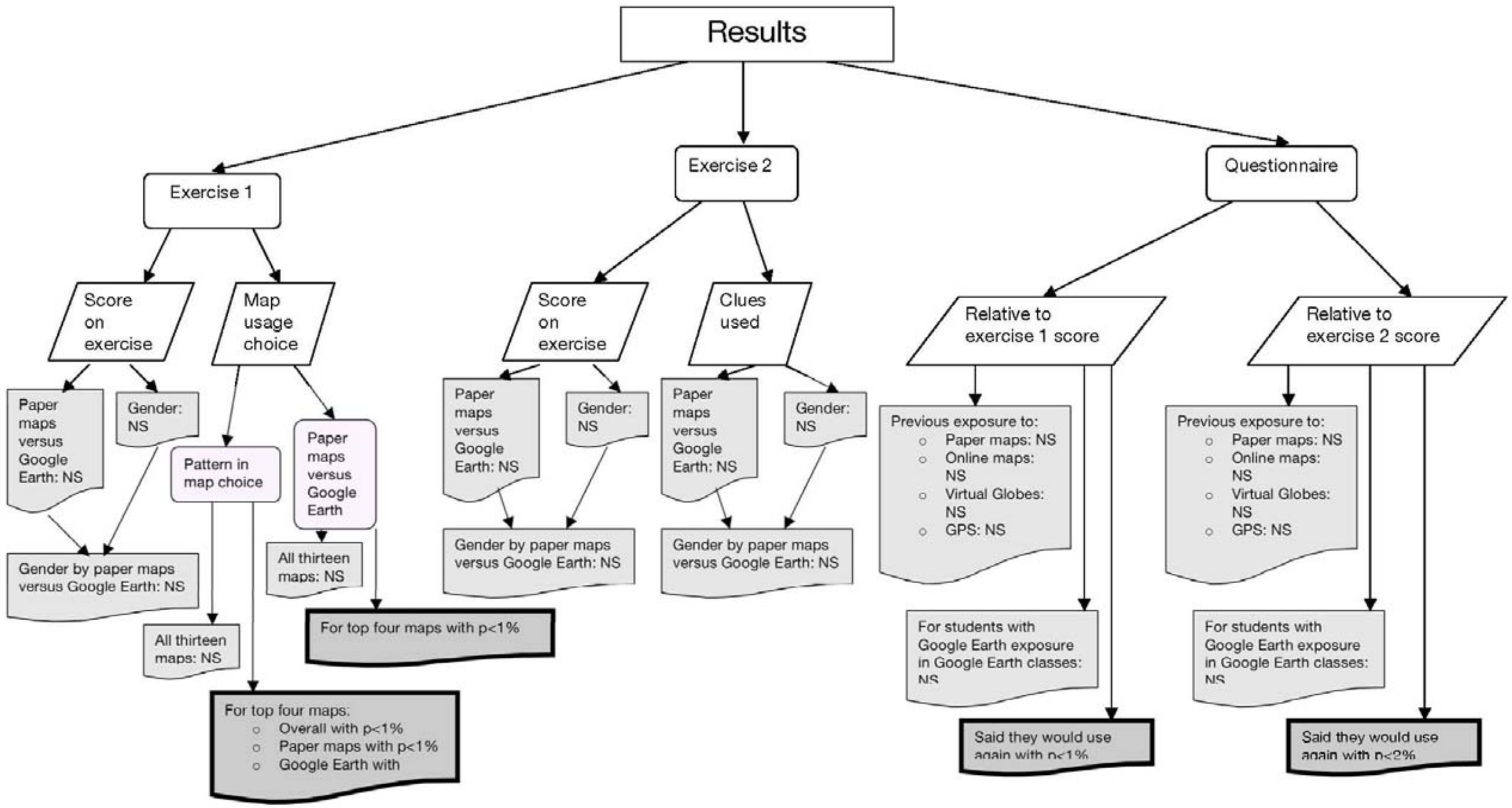


Figure 11: Summary of results.

5 Discussion

This chapter will analyze the results presented in Chapter 4 by proposing reasons for these results and suggesting lessons that can be learned from the findings. This section will look first at the results in light of the methodology and the set up of the experiment before examining the results of each of the three hypotheses laid out in Chapter 1 and finally discussing some of the greater general issues that the outcome that this study raises.

5.1 Discussion of methodology

This study used four classes of students age 11 to 12 to look at the differences between those who did an activity using paper maps and those who did the same activity using a virtual mapping program. Building off of the suggestions of previous studies, this exercise was fluidly integrated into the language arts curriculum of this class. Furthermore, with both methods the activities were built to fit into the constructivist pedagogy and be interdisciplinary by bringing in elements from many academic areas. Although in these ways this study sought to conform to earlier research, this exercised diverged from the suggested methods in two important ways: firstly, by only being a one day activity and secondly by not utilizing some of the advanced functions of Google Earth.

The idea to do an activity over only one day was a conscious decision since this is the way that 80% of teachers have opted to use geospatial technologies in their class (Kerski 2003). While at least one study shows that student attitude and self-efficacy can in fact be effected by only one day of work with a GIS (Baker and White 2003), this study hopes to address whether spatial thinking can be influenced by the use of virtual globes during one day of activities. Several authors contend that any difference in spatial literacy is unlikely to result from only one day of work, advocating instead for a lengthier integration (Patterson, Reeve et al. 2003; Joseph 2004). The results of this study seem to confirm this belief. The differences between students using paper maps and those using Google Earth in terms of how well they scored on the exercises are non-significant. These results, and those of previous research, support the idea that a long-term integration of geospatial technologies is necessary for new spatial thinking skills to be developed.

This one day model of teaching with virtual globes has further implications when considering the set up of the exercise. Since students in both groups had only one day to do this activity, the Google Earth students may have been at a slight disadvantage since they also had listen to a five-minute introduction to the application and learn how to use the program in this one class time. Furthermore, although the students as a whole were very adept at using the application, occasionally students got stuck zoomed in beyond recognition or with the globe turned upside down, etc, and needed the assistance of the researcher to get themselves reoriented and back into the activity. As will be discussed further in regards to each specific hypothesis, this could be one reason for the lower average test scores in the classes using Google Earth—on top of simply doing the activity, they also had to adapt to this new platform.

The second way that this study did not adhere to the suggested best ways for geospatial technologies to be integrated is by not using any of the features in Google Earth that make it unique. This was unfortunately necessary in order to have a control group in this study; the students could not do anything in Google Earth that could not also be done with paper maps because you could not compare the results. This runs counter to what most experts say about using geospatial technologies in the classroom who claim that the only way get the most out of these tools is by using them for tasks that cannot be accomplished by other means. Here the students were only able to make use of the tool for visualizing the data, not for any other type of analysis and therefore an actual 'value-added' situation of using geospatial technologies was not achieved. This again could be one reason that the students using Google Earth did not attain better results than those who used paper maps. Perhaps if the students were asked to take advantage of their ability to explore the country at different scale as well as the content provided by Google Earth and maybe even build some of their own placemarks and data, the students would have gained more spatial thinking skills. Unfortunately in this situation it would be impossible to compare those results to what could be provided in paper form.

Other considerations for discussion include the size and characteristics of the sample as well as the testing of the students. Although seventy students participated in this study, the students were working in pairs so the sample size is reduced to thirty-five worksheets. Of course, half of these students did the activity with paper maps and half did it with Google Earth so that reduced the sample size even further for each method. This small sample size is a reason that many of the results were not significant. Furthermore, the samples were as random as possible—the students could not be divided between the two methods within a class and it made more practical sense for the two morning classes to use paper maps. This of course is not as ideally random a sampling as it should be for such a study, but it was the best possible way given the situation. One way to determine the randomness of the sample would have been to do some sort of pre- and post-testing of general spatially ability. This would have provided not only a sense of whether the students were starting from the same base, but also indicate differences in spatial thinking between students using the two methods.

The fact that the students did the exercise in pairs clearly had a large impact on the results. The choice to have the students work in pairs was thought to fit more into student-centered constructivist pedagogies where students are encouraged to think by talking over their ideas with other students. While working in pairs fits into constructivism and it probably more enjoyable for the students, it doesn't necessarily make for useful results. As mentioned in the results section, this means that although the data for gender and experience for each student were collected, this data cannot be used to their greatest capacity since the worksheets were filled out in pairs. As presented in Section 4.3, each pairs experience was not well correlated, meaning that each partner had very different previous exposure to geospatial technologies. This is emphasized when looking at the pairings of students in the Google Earth sections in regards to their previous exposure to Google Earth. Out of the 19 pairs in these classes, in only five pairs did neither student have any Google Earth experience. That means that in almost three-quarters of these pairs, at least one student had used the application before and could bring their experience to the activity. Although with the questionnaire the pairs clearly affect the ability to create interesting results, previous research has shown that with similar activities gender is a non-significant factor (Kerski 2003). So while working in pairs made for a better class and more fun experience for the students, it prevents a real analysis of how previous exposure to geographic technologies affected the students' work.

Another issue worth discussing in regards to the results of this experiment is that of who was conducting the day's activities. Since the objectives of this study are to look at what and how the students are learning from this activity and not focus on quantifying the teaching side of the experiment, the researcher conducted the class during the day. This is important to consider since this means that an expert in the field was teaching the class. This means, for example, that the situation was probably as ideal as it could be in terms of the time that was needed to work out technical glitches during the activity since the researcher was very familiar with the application. So while the short time it took to teach the students about Google Earth and help them when they got stuck may have influenced the results, were the instructor to be less proficient with the technology the results may have been affected even more.

5.2 First hypothesis: effect of method on worksheet scores

The first hypothesis of this exercise looks at the scores attained by the students on the two exercises. The null hypothesis states that there is no difference in the scores for the two groups. For both the first and second exercise, no significant difference in scores was found even though students using paper maps had a higher average score for both exercises. So although students in this study did better with paper maps in terms of score, since the result is not significant it cannot be extrapolated beyond this study and therefore the null hypothesis must be accepted. It is important to look at why, even without a significant difference, students in this example did better with paper maps before examining the implication of the fact that there was no statistical difference between scores.

Firstly, the students in these classes showed that they were able to provide better answers for the first and second exercises of this study if they completed them with the help of paper maps instead of Google Earth. As mentioned, one reason may have been the extra time the students using Google Earth needed to acquaint themselves with the application and deal with any technical problems they encountered. However small these tasks might be, in a class of only an hour even just five minutes of time is a large chunk of the class. This notion is supported by the results of the questionnaire: while 67% (n=67) of students in the classes use paper maps at least once a month, only 35% (n=66) use a virtual globe. Clearly the students are accustomed to working with paper maps while virtual globes are a platform they encounter less frequently. The time it would take students to familiarize themselves with the Google Earth platform may have lead to less time for the students to work on the activities and therefore the students using Google Earth were not able to score as high on the exercises.

Furthermore, statistically, this sample is not ideal for drawing conclusions. Although the averages were different for the two methods, the sample size was relatively small and the standard deviation fairly large for each exercise and for each method. This suggests that there was a wide range in both of the sample groups so that it is risky to draw conclusions from these statistics; a notion confirmed by the lack of significance in the differences between the groups.

Another possible reason that the students using paper maps scored better than those using a virtual globe application is that the students using Google Earth seemed more likely to be distracted by the program than those using paper maps. While with paper maps the students had nothing else to distract them and were quite focused on the task, with Google Earth both the researcher and the teacher felt that they constantly needed to be walking around the classroom and talking to the students about their assignment to make sure they stayed on task. Several of the pairs were seen to be zooming around to places other than those of question in the study. This is a commonly observed problem with Google Earth and a curse of the easy interface: "…the tool becomes entertainment, geographic entertainment to be sure, but entertainment just the same, enticing the students to flip or rotate the Earth, fly to places that are not part of the lesson, or add content that is not part of the lesson" (Kerski 2007 p. 132). While many students had previous exposure to Google Earth (71% with n=66), it was still exciting for them to look at their houses and explore the various YouTube and Wikipedia links that may clutter the screen. A recommendation might be that before launching into a classroom activity using a virtual globe, students have one class period to play a bit, explore their house and community, and click on links. This would serve a dual purpose of getting some of the distraction out of their system while familiarizing the students with how to navigate in that program so that the actual lesson can go more smoothly. Although as a whole the students in classes using either method were good at staying on task, it was definitely more of an issue for the students using Google Earth and one that might have cost them some points on their scores.

While these are some of the possible reasons that students in these classes averaged lower with Google Earth than with paper maps, it is also notable that statistically there was no significant difference between scores of students using either method. Some of the students using Google Earth had no experience with this application and yet, statistically, there was no major difference between how well they did compared with the students who had used the application before. This speaks to the accessibility of the application—that students with little or no exposure to the interface can attain scores nearly as high and statistically the same, as students using paper maps, a format that most were quite familiar with. This is an example of how, with virtual globes and other easy to learn geospatial technologies, the focus of the teacher can move away from teaching *about* the technology to teaching *with* it. It is important to consider that even though the students using Google Earth averaged slightly less than those using paper maps, this difference is not statistically significant, indicating that learning the technology did not interfere with the their ability to do the exercises.

Additionally, while students using either method were able to display similar abilities of spatial thinking, the students using the virtual globe were simultaneously gaining technological skill. This is the added bonus of teaching with a geospatial technology; students are not only learning about the content of academic discipline(s) but also learning how to navigate in a computer platform, getting to know a new resource for research and projects, and picking up basic skills and concepts of geospatial technologies (layers, georeferencing, interactivity, etc) that are transferable to more complicated desktop GIS applications. Kerski, in a similar study of high school learning with GIS, puts it well: "non-GIS students learned the content, but GIS students learned new skills in addition to the content" (Wanner and Kerski 1999 para. 26). So although the results may not be significantly statistically, they are significant in substance since they prove that students who use it can learn both the content of the activity and the application, without it taking a major toll on their grades.

Ultimately, the first null hypothesis was supported with the statistical analysis of the final scores showing there to be no significant difference between the two methods. Although the use of Google Earth was not shown to improve the spatial thinking ability of the students beyond that of paper maps, there are costs and benefits to be weighed with either method.

5.3 Second hypothesis: learning method with paper maps versus Google Earth

The second hypothesis looks at the differences in learning by analyzing how students approached answering the two exercises. Learning methods were determined by looking at the maps used in order of preference for the first exercise and by examining the clues used to answer the second exercise. A significant difference in pattern of map choice can be seen between the two methods, although there is no difference between the clues used in the second exercise.

Map choice helps to indicate how the students tackled answering Exercise 1. Notably, the students were given seven slots to list the maps they used in order of importance. When using a x^2 test to look for a pattern, no pattern could be found, or difference in pattern for each method, if all seven maps listed were used in the calculation. This is likely because there were only thirteen choices so with seven possibilities, many of the thirteen choices would have been accounted for. More interesting is to look at the maps that the students chose as their top four variables. In this case, looking at the top four choices overall, the maps chosen by either the paper maps groups or the Google Earth group, or the comparison of the choices of paper maps to Google Earth, reveals a statistically significant pattern.

The most interesting, of course, is the comparison between the two methods; Figure 6 in Chapter 4 shows the differences in the top four choices. It appears that the students using paper maps were drawn more to just a few maps, whereas the students using Google Earth used a more diverse array of maps for their primary analysis. As can be seen in Figure 7 of Chapter 4, the maps used by the students using paper maps were more likely to be the ones presented to them first in the packet they received while for Google Earth the students did not seem to be influenced by the order in which the maps were placed in Google Earth. This suggests that with the maps presented to the students as layers in a computer application, the students are more likely to explore all of the options. There are several possible reasons for this. Since the maps are all overlayed directly on top of each other, when the students were choosing a place to put their new capital, it would have been quite easy for them to look at a location and then analyze its assets by clicking through all of the given maps layers. Doing the same thing with paper maps would require that the students estimate a location on each of the maps provided to them since the maps were not layered exactly atop one another. These significant results suggest that students are more likely to explore all of the data given to them in Google Earth than they are in a paper map format such as the one used in this study.

It is also interesting to look at the differences in topic in the maps that students using each method chose. Some of the most frequently used maps for the students using paper maps were the topography/base map, elevation, annual rainfall, annual temperature, and transportation/national park maps. For the Google Earth students the most popular maps were topography/base map, elevation, gold mine locations, land cover, and population density maps. Although both made interesting selections, the maps chosen by the Google Earth students could be construed as slightly more abstract and complex. It is important to note, however, that no measures were taken to determine how well the students understood the content of the maps they were using to make their decision.

In the second exercise, the clues the students used to match the letter to where the student lived in Ghana were the data for quantifying any difference between the two methods. A two-tail t-test reveals no significant difference in the percent of map or text-based clues students used with either paper maps or Google Earth. As Table 5 in Chapter 4 presents, however, students in the paper maps group on average used slightly more map-based clues. This could be because the paper maps were right in front of these students—they did not have to click on each layer to find the necessary information. On the other hand, this could also be a result of the ease/enjoyment of using placemarks for the students in the Google Earth classes. It may be that for the students who had all the information in paper form, it was much nicer just to go back to the maps whereas the placemark format made reading the descriptions of the places more enjoyable. For these students, it might have been more palatable to read the description of each place one at a time in a placemark, rather than wade through a packet of information about these places. Regardless, ultimately there was little difference in which clues the students used between the two methods, although students using paper maps slightly favored map-based clues.

It is also important to consider here that the sample size was quite small. As mentioned earlier in this report, students were encouraged to focus on finishing the first exercise completely before moving on to the second. So while the sample was already smaller for Exercise 2, a few of the students ignored/forgot the part where they were asked to circle which clues they used, making the sample size even smaller, at just five pairs per method.

Also, the standard deviations for each of these samples were again quite high, making it even more complicated to draw conclusions from this data.

The upshot of this discussion is that the second alternate hypothesis, regarding how the method of learning affects the students' approach the problem, is supported by the results of the first exercise, but not by that of the second. From the results of the first exercise, students using Google Earth seemed more likely to explore all the layers and possibly even use more sophisticated data whereas the students using paper maps were most likely to use those first in order in their packet of maps. In the second exercise no difference was shown between whether students were more likely to use map- or text-based clues with either method. However the sample size for this portion of the analysis was extremely small and therefore difficult to determine anything from.

5.4 Third hypothesis: influence of previous exposure to various forms of geographic technology

The last of the three hypotheses looks at whether students' previous exposure to paper maps, online maps, GIS, virtual globes, or GPS, in any way affected how well they did on this activity. Unfortunately since the students were doing the activity in pairs to support the constructivist teaching pedagogy, pairing the individual questionnaire results with the results of the activity is problematic. ANOVA tests comparing previous exposure to each of the above five 'technologies' to both the score for Exercise 1 and for Exercise 2 returned no significant results, it is likely that this disconnect between the evaluation of their worksheet and that of their previous exposure had an influence on the results. For example, in the pairs of students using Google Earth, in all but five of the pairs at least one student had experience working with a virtual globe that they could contribute to the activity. However, these results still raise other topics for discussion.

As mentioned in the methodology section, the median household income for this community is quite a bit higher than the national average, suggesting that this a fairly privileged community. As such, the results of the questionnaire show that only four students out of the 70 who took part in this activity marked 'don't know/never' for all four categories based on computer-based geographic information—online maps, virtual globes, GIS, and GPS—and only ten of these students marked 'don't know/never' for paper maps. This means that a vast majority of the students are frequently exposed to geographic information platforms and therefore are likely comfortable using them, whether in paper or computer form. This exposure may also add to the logic of using tools like paper or digital maps in the classroom; for the students in this activity, maps are a tool that they are comfortable working with and therefore a good one to be employed in their learning.

Unfortunately, it could be that this familiarity of students to computer-based geographic interfaces that helped lower the average scores in this example for students using Google Earth. Some of the students who were clearly adept at using Google Earth were the most often off task since they wanted to make use of the other tools they knew about instead of staying on task. They would much rather, for example, fly around using the flight simulator than read information about Ghanaian cities and towns. This is a great challenge of using any technology in an educational setting; you need to be able to balance the lesson so that it is doable for students who have no familiarity with the application but still an interesting challenge for those who are more proficient at using the technology.

So while it is difficult to draw conclusions from the questionnaire relative to the work the students did on the exercises, it is still informative to take the results of the questionnaire into consideration when analyzing the results of the day's activities. Ultimately, though, it seems that the third null hypothesis is supported in this case and previous exposure had no impact on the results of the exercises.

5.5 General discussion

This section will look more generally at the results and discuss observations and considerations based on the work that has been presented.

Notably, both of these activities exemplified constructivist pedagogies. The activity sought to be student-centered, with the teacher available to answer questions and help the students explore what intrigued them most, but not to direct the approach that they took to address the questions. The students were then able to discuss the possible answers with each other and bounce ideas around. The fact that this was achieved with either method is important because although virtual globes and other forms of technology provide wonderful platforms for this type of learning, if the teacher does not have access to the technology or skill required to use such a tool, it is still possible to attain constructivist teaching methods without the technology.

In regards to the paper maps, the students in these classes showed that they were able to achieve slightly better average results than their counterparts using Google Earth, although the difference was not significant. In general the students in the paper maps classes seemed more attentive although despite the fact they seemed more focused on the work, fewer pairs were able to complete both exercises than in the classes using Google Earth—with only nine paper maps pairs and fifteen Google Earth completing the both exercises. Since the students averaged higher in the paper maps group, this seems to be an example of quantity versus quality for the two methods.

Although the students using Google Earth in these classes did not do as well in scoring as the students using paper maps, there are still other quantitative observations to be figured into this analysis. Students using Google Earth were much livelier than those using paper maps; the students in the Google Earth sections were eager to show off interesting things that they had seen in the application to their teacher. In fact, in a particularly poignant example of constructivism in action, after one pair had finished the activity, they were exploring their hometown and the teacher was asking them to show her where various things were in the town. As was evidenced in the questionnaire feedback, the students were enthused by their experience with Google Earth and were eager to use it again either at home or at school. In this way, through their interest in using Google Earth at home, students *did* demonstrate some ability to reapply the concepts they learned—albeit more likely in terms of technological skill rather than spatial thinking. Fortunately, one of the benefits of Google Earth is that the students *are* able to use it at home as the version we were using it also available to them for free, provided they have Internet access.

Additionally, although the application was a distraction to a degree, this very distraction may have given the students a richer appreciation for the country of Ghana by allowing them to see it in the context of the entire planet. While students using paper maps only saw Ghana as an isolated country, students using Google Earth were 'flown' into Ghana, giving them a sense of its size and position in the world relative to what is around it. Despite the fact that spatial literacy may not be increased more with Google Earth than with other methods, geographic literacy may well be, as students see what is around the country of Ghana. Furthermore, though students were told to focus on the lesson for the sake of this study, if they had chose to look at some of the placemarks provided by the application such as the Wikipedia links, they might have been able to realize a richer sense of place for the parts of Ghana they were looking at. So although statistics show that Google Earth does not offer any benefit over paper maps in regards to spatial thinking ability during the activity, the application offers students and teachers the possibility to explore and learn beyond the activity that paper maps do not.

These observations are reinforced by the comments of the regular teacher of the class who was solicited for feedback shortly after the activity was completed. The teacher noted that she "thought the paper maps made the project more easily accomplished" but that she felt "that Google Earth was a lot more memorable and fun." Since she works with the students on a daily basis, she has the ability to gauge their reaction and felt that it was very accessible for these students and that they thoroughly enjoyed using Google Earth. Perhaps the most interesting reflection from her response was the following:

> I think Google Earth is a fabulous education tool and I can think of a million uses for it in schools. I am now teaching a novel about a boy in Pakistan, and I might have the kids go to the computer lab to find out about Pakistan and Lahore, the city that is the setting.

A demonstration of the applications such as the one provided in this study was all the teacher needed to make her understand what a useful tool virtual globes can be in a classroom setting.

Several other lessons can be learned from this Ghana exercise. For teachers interested in using Google Earth, it is important that they have a fairly fast Internet connection, as that was one of the only things students complained about with the application. If they were complaining in an exercise such as this where few of the 'advanced' features of Google Earth were being employed, likely these problems would only be heightened in a situation where students were creating their own placemarks and layers and demanding more of the applications. This needs to be taken into consideration as the students were even fussing here, where the processing was fairly quick by most standards.

In summary, the results of this day in the classroom show that there is little difference in the demonstrated spatial thinking ability between students using each method. Their experience with various forms of geographic technologies does not seem to influence their ability to complete the activity although the difference of paper maps and Google Earth as platforms does seem to at least partially affect how the students approach their activity. Both methods show an interesting way of integrating maps and spatial thinking into a language arts class and while students were more focused and in these classes achieved better results with paper maps, there are additional benefits to using Google Earth that were not necessarily measured in this study. Virtual globes, through the simplicity of their interfaces and the ease with which they can be integrated into any classroom, have opened up the doors for more research in the field of geospatial technologies to look at aspects of integration not measured in this study.

6 Conclusion

The objective of this study was to look quantitatively at student learning with a virtual globe application. Virtual globes are a solution to help overcome some of the obstacles of employing more traditional geographic technologies as a teaching tool in the classroom, such as time and expense. Quantitative research is necessary to determine whether virtual globes such as Google Earth can maintain some of the benefits of GIS—like teaching spatial thinking—while overcoming these obstacles. Spatial thinking skills are important to develop at an early age as technology has increased the amount of spatial data we must reason with on a daily basis; students need to become spatially literate in order to function at a high level in today's society. This study used a sixth grade class learning about Ghana as a platform for research on teaching spatial skills with virtual globes by having two classes do an activity with paper maps and two others do the same activity with Google Earth.

The first hypothesis compared scores for the two methods on how well students did at spatial analysis. While statistically the difference in scores was non-significant, in this group the students using paper maps averaged slightly higher than those using Google Earth for both the first and second exercises of the activity. These results, however, do not necessarily reflect poorly on Google Earth; these results show that students using a virtual globe, a format they are less familiar with than paper maps, were able to quickly adapt to this platform and score nearly as well as those students using paper maps. This is concrete evidence of how accessible the program is for students—with virtually no introduction the students could jump right in and start using the program with only a few minor hiccups. The five minutes spent introducing the students to how to view layers and placemarks in Google Earth may also have had an effect on how well they did as this took a few minutes out of the already short amount of time that the students had to work on the activity. Time may also have been an issue for the students using Google Earth since these students seemed noticeably more distracted during the activity than the students using paper maps; the students using Google Earth wanted to explore their hometown and not focus on the assignment. One recommendation from this study is that before teachers use such a program in their classroom, they give the students one day to acquaint themselves with the technology and get some of the playing out of their system. Notably, while the students using Google Earth may have had slightly lower scores, they were simultaneously developing technological skills as they were working on the activity. Although students using paper maps scored better on average on their analysis, this difference was not statistically significant and furthermore, is not necessarily a sign of a major weakness, given the circumstances.

The second hypothesis attended to how the students approached answering each question. Results showed a statistically significant difference in pattern between the top four maps students factored into their analysis of the first question. In analyzing this difference it appears that students using paper maps were more likely to use the maps presented to them first in the packet they were given whereas Google Earth students seemed to choose from a wider variety of maps, suggesting that something about the format in which the maps were presented to them in Google Earth encouraged them to look through all the options. While there was this statistically significant difference between the two approaches for each method in the first exercise, no such significant difference could be seen between the clues used for either the paper maps or Google Earth groups, although the averages showed a slight preference for map-based clues for the students using paper maps. Again, although this difference may not be statistically notable, is it substantively significant in that it may mean that the students using Google Earth had no problems adapting to using placemarks, since they were actually more likely to use the information contained in the placemark than in the maps layers. It seems that for the second hypothesis, a statistically significant difference in approach was demonstrated in the first exercise, but not for the second exercise.

Finally, the third hypothesis sought to look at how the previous exposure of students to various forms of geospatial technologies, ranging from paper maps to GPS, affected how well they did on the activities. Unfortunately for this hypothesis, the structure of the methodology did not allow for such a comparison to be effectively carried out and—unsurprisingly—none of the relationships between technological exposure and scores had any statistical significance. These results were none-the-less interesting in that they provided insight into the students' exposure to geographic information and support the claim of this paper that students are increasingly confronted with the type of geographic information that requires well-developed spatial literacy faculties to have a full appreciation for what is presented to the viewer.

Along with these quantitative results, qualitative feedback was solicited from both the teacher and the students who used Google Earth. The teacher observed that while students using both methods were enthusiastic and the activity was more easily accomplished with paper maps, the exercises were more memorable and fun for the students who used Google Earth. The Google Earth students were extremely enthused by the application. While a handful found the program somewhat confusing, when asked whether they would like to use the program again at home or at school, the answer was a resounding 'yes.' These results show that even if virtual globes have not been shown to develop spatial thinking skills more than traditional teaching materials, students and teachers are still enthusiastic about this application and can see its potential as a resource and learning tool.

While these findings can help inform both other researchers and teachers, there are some considerations to be taken in account. Firstly, the sample size can be considered small by most standards, meaning that it is difficult to draw conclusions from the results. Additionally, this study tested the spatial thinking skills that students gained after just one class of working with Google Earth; while the results of this study did not come out in favor of geospatial technologies, a longer-term integration may yield different results. Furthermore, for the sake of a control group, few of the features that make Google Earth unique were utilized—again, the results might be more substantively and statistically significant if students were to have employed some of these tools. These factors may not only account for some of the results, but also offer future directions for research on this topic.

Were this experiment to be conducted again, it would benefit the results to change or modify some of the conditions of this study. A larger sample size would no doubt provide more interesting results and perhaps reveal that the difference in score observed in the results presented in this study can be generalized outside of these students. Furthermore, while the choice to do the activity during one day was a conscious decision and revealing in itself, having the students continue to do more with maps and virtual globes and undergo additional testing could help affirm whether or not longer term integration yields better results for virtual globes. Additionally, it would have been informative to have students do two activities and switch which method they are learning by for each to get their feedback on which of the two methods they prefer. Lastly, although having the students work in pairs was more interesting for them, this meant that the questionnaire results could not really be used to correlate with how well the students did on the exercises—have the students work alone would have allowed for a conclusion to be drawn on this topic, as well as increased the sample size two-fold.

5.2 Future directions

Online mapping applications such as Google Earth are increasingly being used in classroom settings, which therefore warrants further research. The advantages to using technology may stretch beyond what is measured in this study to things like attitude and self-efficacy towards technology or the subject matter, as was measured in regards to GIS by Baker and White (Baker and White 2003). As mentioned, studies on student learning from more advanced functions or over longer periods of time may favor geospatial technologies and could help teachers understand how to best integrate these applications into their classrooms. Also interesting would be to look at how well the students retained the content of the exercise (Linn 1997) and/or how well they were able to reapply the concepts on a general spatial skills test (Wanner and Kerski 1999). Additionally, while this study is focused on the student learning side of using geospatial technologies in the classroom, it would be instructive to 'flip' this study to look also at the teaching side and how different methods of teaching affect the results. Finally, a comparison of what and how students learn from a variety of different geospatial technologies would help direct educators to the best platforms, whether it be looking at virtual globes relative to GIS or through evaluating the various virtual globe applications, which each have their own interface and functionality. After all, as Donaldson notes, it's no longer as much a question of *if* technologies will be integrated into classrooms, but *how*; research would do well to investigate the most effective methods for teaching with geospatial technologies (Donaldson 2001). While this research seeks to fill a small gap in studies on geospatial technologies by providing a quantitative analysis of the use of virtual globes to teach spatial thinking, there are many other topics that ought to be covered.

Overall, although this research did not demonstrate that Google Earth encouraged a higher order spatial thinking than did paper maps, some difference in approach with each method can be seen. Both methods attempted to provide an activity for the students that fit well within constructivist pedagogies, a framework in which all the students seemed to thrive. Although this study did not seek to determine whether virtual globes in fact do overcome obstacles of implementing traditional GIS such as cost and time, the fact that students were able to immediately use the application with hardly any introduction, speaks to the accessibility of this program. The hope is that this research encourages teachers to use geospatial technologies in their classroom through the enthusiasm displayed by the students and teacher, with the warning that the development of spatial thinking skills beyond what can be achieved with more traditional materials can not be assumed through the use of a virtual globe; students may indeed be able to learn more spatial skills with programs like Google Earth but to achieve this end, different means may have to be employed. Regardless of the methodology, it is important that teaching spatial literacy become a major component of teaching curriculums around the world so that—as spatial information becomes increasingly prevalent though the development of place-based technologies—students understand how to comprehend and make the most of the information presented to them.

BIBLIOGRAPHIC REFERENCES

Alibrandi, M. (2003). GIS in the classroom. Portsmouth, NH, Heinemann.

Audet, R. and J. Paris (1997). "GIS Implementation model for schools: assessing the critical concerns." Journal of Geography **96**(6): 293-300.

Baker, T. (2000). "Applications of GIS in the K-12 science classroom." ESRI User Conference Retrieved 1 August, 2008, from http://gis.esri.com/library/userconf/proc00/professional/papers/PAP265/p265.htm.

Baker, T. (2001). "The history and application of GIS in K-12 education." Retrieved October 6, 2008, from http://www.gisdevelopment.net/Education/papers/edpa0003.htm.

Baker, T. (2005). "Internet-based GIS mapping in support of K-12 education." The Professional Geographer **47**(1): 44-50.

Baker, T. and S. Bednarz (2003). "Lessons learned from reviewing research in GIS education." Journal of Geography **102**: 231-233.

Baker, T. and S. White (2003). "The effects of GIS on students' attitudes, self-efficacy, and achievement in middle school science classrooms." Journal of Geography **102**: 243-254.

Battersby, S., R. Golledge, et al. (2006). "Incidental learning of geospatial concepts across grade levels: map overlay." Journal of Geography **105**(4): 139-146.

Beatty, L. (1996). "Using a geographic information system in an introductory geology class to demonstrate the effect of geological processes on human habitat." The Compass: Earth Science Journal of Sigma Gamma Epsilon **72**(4): 130-133.

Bednarz, S. (2004). "Geographic information systems: A tool to support geography and environmental education?" GeoJournal **60**: 191-199.

Bednarz, S. and R. Bednarz (2004). "Geography education: the glass is half full and it's getting fuller." Journal of Geography **56**(1): 22-27.

Butler, D. (2006). "The web-side world." Nature **439**(16): 776-778.

Chandler, T. and H. An (2007). "Using digital mapping programs to augment student learning in social studies." Journal of Online Education **4**(1).

Doering, A. and G. Veletsianos (2007). "An investigation of the use of real-time, authentic geospatial data in the K-12 classroom." Journal of Geography **106**: 217-225.

Donaldson, D. (2001). "With a little help from our firends: implementing geographic information systems (GIS) in K-12 schools." Social Education **65**(3): 147-150.

Downs, R. and A. DeSouza (2006). Learning to Think Spatially. Washington D.C., National Academies Press.

Fitzpatrick, C. (2001). "A trainer's view of GIS in schools." International Research in Geographical and Environmental Education **10**(1): 85-87.

Goodchild, M. (2006, Fall). "The fourth R? Rethinking GIS education." ArcNews Retrieved 1 August, 2008, from http://www.esri.com/news/arcnews/fall06articles/the-fourth-r.html.

Google. (2008). "Truly global." Retrieved 25 October, 2008, from http://google-latlong.blogspot.com/2008/02/truly-global.html.

Joseph, E. (2004). "Community GIS: University Collaboration and Outreach with K-12 Teachers." ESRI User Conference Retrieved 1 August, 2008.

Keiper, T. (1999). "GIS for elementary students: An inquiry into a new approach to learning geography." Journal of Geography **98**(2): 47-59.

Kerski, J. (2001). "A national assessment of GIS in American high schools." International Research in Geographical and Environmental Education **10**(1): 72-84.

Kerski, J. (2003). "The implementation and effectiveness of geographic information systems technology and methods in secondary education." Journal of Geography **102**: 128-137.
Kerski, J. (2007). The world at the student's fingertips. Digital geography: geospatial tehcnologies in the social studies classroom. A. Milson and M. Alibrandi. Charlotte, NC, Information Age Publishing: 119-134.
Kerski, J. (2008a). Geographic Technology teacher/professional network: email, 6 September. K. Clagett.
Kerski, J. (2008b). "GIS in Education in Taiwan." GIS Education Community Blog Retrieved 24 November, 2008, from http://blogs.esri.com/Info/blogs/gisedcom/archive/2008/11/21/gis-in-education-in-taiwan.aspx.
Kerski, J. (Unknown). "Spatial inquiry using web-mapping tools." Retrieved 1 September, 2008, from http://www.josephkerski.com/spatial_inquiry_using_web_mapping_tools.pdf.
Kidman, G. and G. Palmer (2006). "GIS: the technology is there but the teaching is yet to catch up." International Research in Geographical and Environmental Education **15**(3): 289-296.
Laituri, M. and S. Linn. (1999). "Graduate Students + Grade Schools (K-12) + Geography Standards + GIS = Great Success!" ESRI User Conference Retrieved 1 August, 2008, from http://gis.esri.com/library/userconf/proc99/proceed/papers/pap324/p324.htm.
Linn, S. (1997). "The effectiveness of interactive maps in the classroom: a selected example in studying Africa." Journal of Geography **96**(3): 164-170.
Lisle, R. (2006). "Google Earth: a new geological resource." Geology Today **22**(1): 29-32.
Merrick, M. and D. Besser. (2005). "SVG and flash: bridging the gap between spatial literacy and GIS competence." URISA PPGIS Conference Retrieved 1 August, 2008.
Meyer, J., J. Butterick, et al. (1999). "GIS in the K-12 Curriculum: A Cautionary Note." Professional Geographer **51**(4): 571-578.
Page, N. (2003). "GIS as a tool for understanding global studies." New Zealand journal of geography **116**: 12-18.
Patterson, M., K. Reeve, et al. (2003). "Integrating geographic information systems into the secondary cirricula." Journal of Geography **102**: 275-281.
Patterson, T. (2007). "Google Earth as a (Not Just) Geography Education Tool." Journal of Geography **106**: 145-152.
Sanders, R., L. Kajs, et al. (2002). "Electronic mapping in education: the use of geographic information systems." Journal of Research on Technology in Education **34**(2): 121-129.
Schaefer, D. (2003). "GIS in schools: experiences and progress in Germany." ESRI User Conference Retrieved 1 August, 2008.
Siegmund, A., K. Viehrig, et al. (2007). "GIS@school--new didactical aspects of using GIS in geography education." ESRI European User Conference Retrieved 1 May, 2008.
Stewart, M., J. Schneiderman, et al. (2001). "A GIS class exercise to study environmental risk." Journal of Geoscience Education **49**(3): 227-234.
Superintendent's Report (2007). Superintendent's report on reconfiguration and the 2007-08 school year. Newburyport, MA.
US Census Bureau (2000a). Summary File 1 100 Percent Data, US Census Bureau.
US Census Bureau (2000b). Summary File 3 Sample Data, US Census Bureau.
Wanner, S. and J. Kerski. (1999). "The effectiveness of GIS in high school education." ESRI User Conference Retrieved 1 August, 2008, from http://gis.esri.com/library/userconf/proc99/proceed/papers/pap203/p203.htm.
West, B. (2003). "Student attitudes and the impact of GIS on thinking skills and motivation." Journal of Geography **102**(6): 267-274.

APPENDICES

Appendix 1: Exercise packet provided to students (from Google Earth example)

NAMES:________________________________

Exercise 1:

The first European country to explore Ghana was **Portugal** in the 1400's (the same time Columbus was sailing to America!). Soon after, other countries from Europe, such as **the Netherlands**, **Sweden**, **England**, and **Denmark**, decided to send people from their countries to the region as well, mainly so that they could try to claim the land as well as any gold or other treasures they found there.

Because at the time the best way to get to Ghana was by sea, **Accra** became the capital since it was right on the ocean. Pretend you are a **modern day** explorer who has to decide where to place a new capital in Ghana—where would you put it?

Explore the different layers in Google Earth showing information about Ghana (including the base layer of Google Earth itself!) and think about what is important to consider when placing a capital. Should it be near the center of the country or on a coast? Near the gold mines or far away? Do you need to be near roads or can you be in the country? Draw a star on the map where you think you would site the capital today:

Source: http://www.enchantedlearning.com/africa/ghana/outlinemap/

1. Why did you choose to locate the capital there?

____

____

____

____

____

____

____

____

____

____

2. What maps did you use to decide where to put the capital? Rate them by which maps you thought were the most important, you don't need to fill out all the lines, just list the maps you used:

1. (most important) ____________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________

Others: ____________________________

3. What **other** information would be good to have to find a new location for a capital?

____

____

Exercise 2:

Much like the creation of the United States brought together many tribes of Native Americans and different European people, the country of Ghana unites several different native groups/languages. By clicking on each of the blue arrows in the 'Places' layer in Google Earth, you can read about six different locations in Ghana. Although today Ghana's people are fairly *heterogeneous*, or mixed, different places in the country are still culturally, geographically, and economically different from one another. Below are several letters from school children in Ghana; read them and using clues from their daily lives, compare that information with what you can learn about each place or what you can see in the maps used in Exercise 1. **Fill in the blank** with where they are from and **circle which clue(s)** helped you the most for deciding where they are from.

Letter 1:

Dear Student,

My life in my hometown of ______________________ in eastern Ghana is very different from yours in some ways, but also probably like yours in other ways. My father is a great chief and because of that I am being trained to also be a chief in our community. Although my city has a lot of people, we still make most of our money from farming. My family brings our food from our farm in the mountains to the market every week to make a living, although my uncle is a fisherman who fishes the lake nearby.

Hedenyuie! (Goodbye!)

Letter 2:

Dear Student,

Hope you are doing well. I'm sitting in my classroom in ___________________ during a break between classes. I'm in school so that some day I can be a police officer—in my big village we need them since sometimes there are problems between the people who live here. I'm lucky, though, because a lot of children in this part of Ghana get very sick because they don't have enough food. My family is mostly farmers, and despite the long hot summers, we've been able to survive so far.

Good luck in your studies!

Letter 3:

Dear Student,

How are you? I am currently in ____________________ where my family just moved. We moved because my Dad is a good businessman and wants to trade in the gold, hardwood, and cocoa industries. The only thing I don't like about it is all the rain—almost 1400 millimeters of rain every year! This city is important to my people, though, and since my mom comes from an important family, it's good for us to be here in the middle of things.

Adinkra! (Goodbye in my native language!)

Letter 4:

Dear Student,

I hope you are having a good day. Here in ______________________ it's raining again since we're in the wet season—we sometimes get over 2000 millimeters (78 inches!) of rain a year. It's hard because that means that there is more erosion, which is bad for the mines. My whole family is involved in the gold mining industry. Gold mining is something that is important to the culture of our people and our chief says that even though it's hard work, we need to work hard at it because it's an important industry to our country and especially to our region since I live in such a small place that we do not have a lot of other industries to keep us going.

Kra! Bye!

Letter 5:

Dear Student,

Up here in the very small _____________________ it's been another dry summer. My family is struggling to raise enough food to feed us so my aunt, uncle, and cousins decided to travel to the South of Ghana where hopefully they can make some money to bring back to the rest of us. Our life is hard up here, we are one of the poorest parts of Ghana; when I get old enough, I will probably also need to go South or perhaps just over the border to Burkina Faso where there are better jobs.

I hope you had a better summer than I am having—the rains probably won't come until October or November!

Letter 6:

Dear Student,

Greetings from _____________________! My life here is quite busy. Although I grew up in the countryside, my parents sent me here to go to school since there are many places here to get a good education. Luckily for me, there are many roads and train lines that lead to my place so my family can come visit me and I can go visit them. Although I enjoy my schooling, I live in the densest part of the country in terms of population so sometimes I miss the countryside.

Have a great day! (I'm studying English in school!)

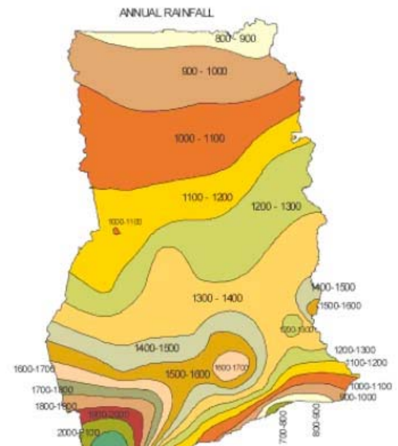
Appendix 2: Maps of Ghana provided to paper map students[1]

Please do not write on me!

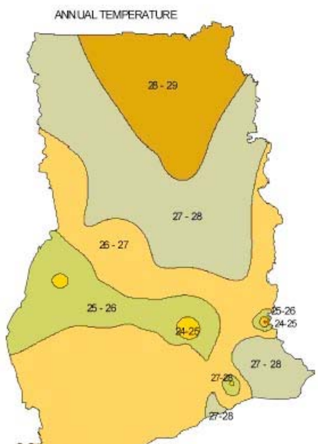
1. Topography and base map

2. Elevation

Please do not write on me!



3. Annual Rainfall

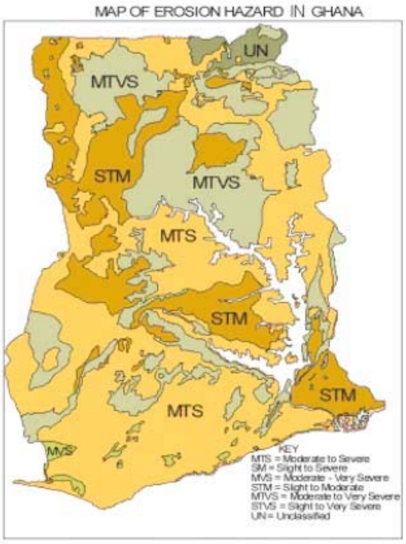


4. Annual Temperature

---

[1] Google Earth students had the same maps presented to them as layers in a KML file.

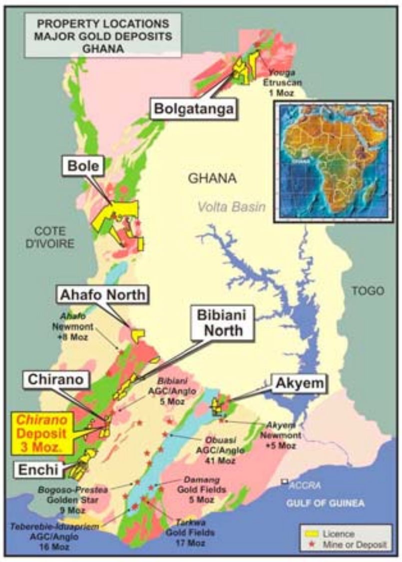
Please do not write on me!



5. River systems

6. Erosion Hazard

Please do not write on me!

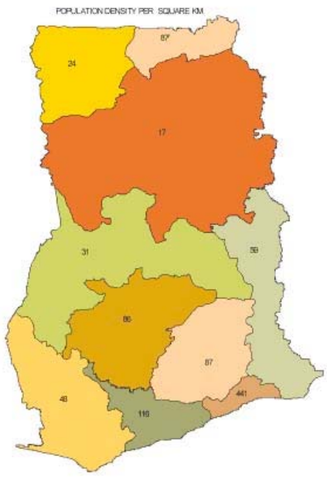


7. Gold Mines

8. Transportation and National Parks

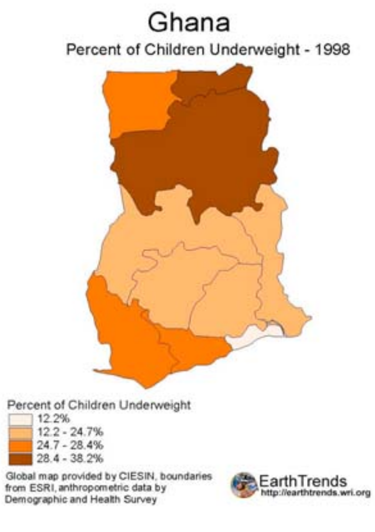
Please do not write on me!

9. Land cover

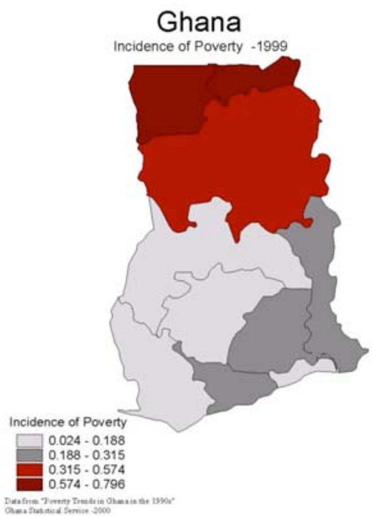


10. Population Density (number is how many people per square kilometer)

Please do not write on me!

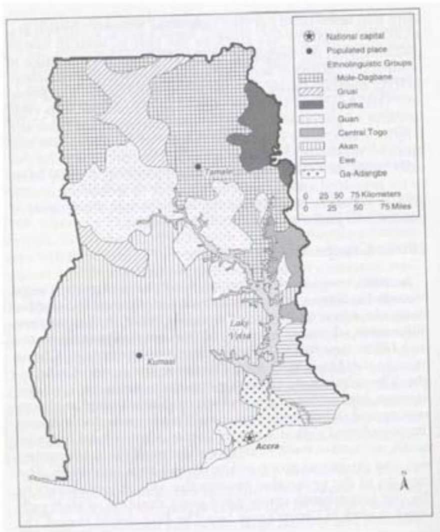


11. Percent of children underweight



12. Poverty rate

Please do not write on me!

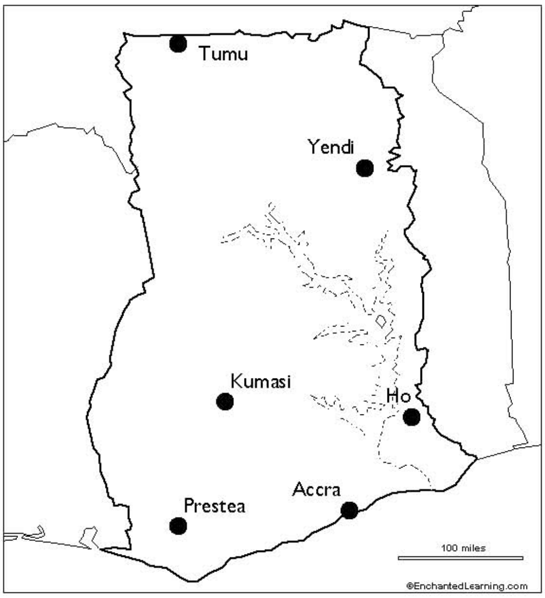


13. Main languages spoken in Ghana

Appendix 3: Place descriptions provided for paper maps students[2]

Please do not write on me!

Exercise 2:



Place Descriptions:

Accra:
Population: 2,905,726 (in 2000)

Language: Ga-Adangbe, but also English, others

About: Accra is the capital of Ghana and is also Ghana's largest city. Ghana is home to the government of Ghana as well as many museums, cultural places, educational institutions, an international airport, and many other things important to Ghana. Because it's right on the coast where there are great beaches, Accra is also a popular tourist destination.

Economy: While farmers used to grow yams and millet in this area, because Accra is located so close to the ocean, fishing has become the main industry. Also, because Accra is the capital and very populated, many people here work in government or business jobs.

[2] Google Earth students had the same descriptions in placemarks as part of a KML file.

Culture: The native people from the area are the Ga and the Adangbe. They people are famous for their elaborate funerals--the deceased are buried in coffins built to look like whatever the families want--even a pencil or an elephant-shaped coffin! The people of the Accra region also love music and dance--in fact, during the slave trade certain rhythms were brought over to the Americans by the slaves that are now what we hear in much Cuban music!

Ho:

Population: 61,658 (in 2000)

Language: Ewe

About: Although it is the capital of the Volta Region, Ho feels more like a large town than a city. The city is known for having several good hospitals that serve the region and is famous for its food market.

Religion: While the Ewe have their own religion based around a god, Mawu, the city has a number of Christian churches, although recently several of the churches have come under attack from Islamic groups.

Economy: This region is largely supported by agriculture, with kola nuts, cocoa, palm oil, and cotton as some of their main crops.

Culture: This region was settled by the Ewe people. The Ewe are based mainly in this southeastern part of Ghana called the Volta region. Their culture is based on each community having a chief, with no one chief ruling all--they are divided into small groups with no 'president'-like person. Unlike in other parts of Ghana, the ability to be chief is passed down on the father's side, instead of the mother's. Arts, dance, and music are all important to the Ewe people. They are famous for weaving brightly colored 'Kente' cloth as well as for their drumming--it is believed that if you are a good drummer it is because they inherited a spirit of a good drummer.

Kumasi:

Population: 1,170,270 (in 2000)

Language: Akan

About: Kumasi is the second largest city in Ghana, located near the center of the country. Kumasi is also at the center of the Asante people, making it one of the most important places for these people, and is home to some of their most important treasures.

Religion: About 80% of the people are Christian, and 20% Islamic--there are also a few people who believe in native religions.

Economy: Kumasi is located in the middle of the rainforest, making it a good place for growing and harvesting hardwoods and cocoa. Gold is also an important part of the economy.

Please do not write on me!

Culture: The Asante people who are the majority of the people in the area pass power down through the mother, although the powerful positions are still held by men. That means that for men to hold power, their mothers or sisters need to have inherited an important position. Although music, art, and dance are important to the Asante, the most famous type of art is the stool--stools are said to hold the owner's soul and are never placed directly on the floor, only ever on a blanket. The chiefs of Asante tribes are always given elaborate stools and no one but the chief is allowed to touch the stool.

Prestea:
Population: 21,844 (in 2000)

Language: Twi (Akan dialect)

About: Prestea is a small city focuses nearly entirely on gold and mining. Like Kumasi, this city falls into the region of the Akan people (which includes the Asante).

Economy: The economy here is based on gold and mining since Prestea is located in the heart of mining country. The mines were controlled by the Akan people (the native people of the area) until the 1800s when foreigners took over operating the mines. There have been many conflicts between the people who live in Prestea and those who operate the mines. The mines have been expanded with explosives whih has caused many of the houses to fall down and dangerous chemicals have been dumped in the water.

Culture: The Akan people are known for the jewelry and weights they make out of various metals and gold. As in Kumasi, the Akan people are organized into small communities, with chiefs that look over each community, and greater chiefs to run several of those communities, and even greater chiefs to oversee the work of those chiefs, etc.

Tumu:
Population: under 20,000 (in 2000)

Language: Mole-Dagbane

About: This large village is located in the northwestern part of Ghana near the border with Burkina Faso. The northern part of Ghana is very poor and starved for resources.

Economy: Agriculture, including corn, millet, groundnuts, okra, shea butter, and rice. Sheep, goats, chickens, pigs and guinea fowl are raised for meat and eggs. Because this region is so poor, many people need to leave for half the year to head south to make money there.

Culture of Upper West Ghana: Because it is so hard to survive in the north of Ghana, most of these communities are very far from their nearest neighbors. This part of Ghana was ruled by many different people and exposed to many different cultures through trade, because of this, each community is very different from each other.

Please do not write on me!

Yendi:
Population: 40,336 (in 2000)

Language: Dagbani

About: Yendi is said to be 'the biggest village in Western Africa.' It is also the capital of the 'Dagbon Traditional Kingdom,' which is the ethnicity of the majority of the people here and a group of people unique to Ghana.

Religion: Christianity and Islam

Economy: Argiculture and iron mining

Culture: The Dagbon people have a chief called 'ya na' who is famed for having a thrown made out of a pile of cow skins. Music and arts are very important to the Dagbon people who, instead of writing down their history, remember stories orally in the form of poems and songs which are accompanied by drums. In 2002, there was a violent conflict between the people of Yendi and those of neighboring Tamale which ended in the current 'ya na' being beheaded. After that conflict, there was a curfew on both cities for some time, with many police officers around.

Appendix 4: Questionnaire provided to Google Earth students[3]

NAME:________________________

FINAL QUESTIONNAIRE:

Thanks so much for your help! I hope you liked learning about Ghana as much as I did!

Just one more thing…

Please answer the following questions **NOT** including the lesson we did learning about Ghana:

How often do you use/look at:

	Don't know/ never	Once or twice a year	Once a twice a month	Weekly	Daily
Paper maps/atlases					
Online maps (like Google Maps)					
Virtual Globes (like Google Earth)					
GIS (Geographic Information Systems					
GPS (global positioning systems)					

1. Did you enjoy working with Google Earth? Why?

____

____

____

____

2. What was your favorite thing about Google Earth?

____

3. What didn't you like about Google Earth?

____

[3] Paper map students completed only the chart portion of this questionnaire.

NAME:________________________

2. Would you ever use Google Earth at home to look up places or for a class project?

____

____

____

____

3. Would you like to use Google Earth more in your class to learn about topics?

____

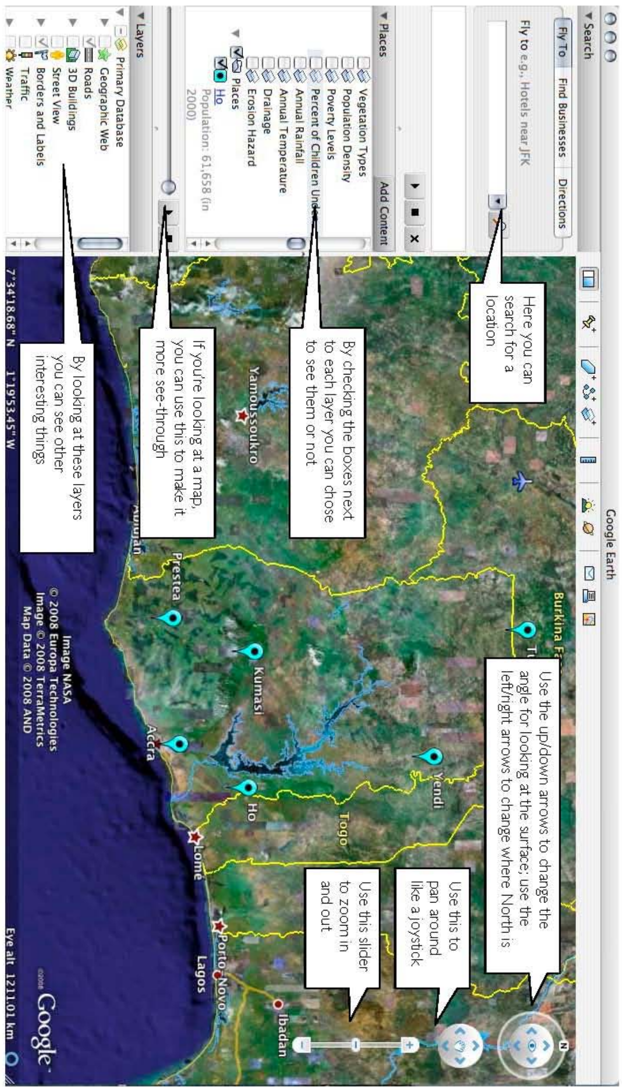
____

____

____

Thanks so much and have a great school year!

Appendix 5: Google Earth help guide provided to students in Google Earth sections



Appendix 6: Full list of results from the activity

General		Exercise 1	Exercise 2			Questionnaire Results[*]				
Student code[**]	GE/ Paper[#]	Score on exercise 1	Percent correct matches	Percent map-based clues	Percent text-based clues	Paper maps/ atlases	Online maps	Virtual globes	GIS	GPS
1-1-1	1	4	0.67	0.33	0.67	4	4	3	1	1
1-1-2	1	4	0.67	0.33	0.67	4	3	2	1	2
1-2-1	1	4	1.00	0.71	0.29	1	2	1	1	1
1-2-2	1	4	1.00	0.71	0.29	1	1	1	1	1
1-3-1	1	3.5	1.00	0.60	0.40	3	2	2	1	1
1-3-2	1	3.5	1.00	0.60	0.40	4	2	3	1	1
1-4-1	1	5				3	3	2	1	4
1-4-2	1	5				4	3	2	1	1
1-5-1	1	4.5				3	1	3	1	2
1-5-2	1	4.5				4	3	3	3	3
1-6-1	1	4				2	2	1	1	2
1-6-2	1	4				2	3	3	1	4
1-7-1	1	3	1.00			5	3	2	1	2
1-7-2	1	3	1.00			4	1	3	1	1
1-7-3	1	3	1.00			5	3	2	1	1
1-8-1	1	3	1.00			4	1	1	1	1
1-8-2	1	3	1.00			1	3	3	1	4
1-9-1	1	2				3	2	2	1	1
1-9-2	1	2				4	4	4	1	5
1-10-1	1	5				3	2	2	1	2
1-10-2	1	5				4	1	2	1	4
1-11-1	1	2	1.00	0.63	0.37	3	2	2	1	5
1-11-2	1	2	1.00	0.63	0.37	4	3	3	1	2
1-12-1	1	2				5	5	4	1	1
1-12-2	1	2								
1-13-1	1	3	1.00	0.19	0.81	3	1	1	1	1
1-13-2	1	3	1.00	0.19	0.81	3	3	3	1	3
1-14-2	1	3	1.00							
1-14-2	1	3	1.00			3	2	2	1	2
1-15-1	1	4.5				3	2	4	1	1
1-15-2	1	4.5				4	3	2	2	1
1-16-1	1	4.5	1.00			3	2	2	1	3
1-16-2	1	4.5	1.00			2	2	2	1	2
2-1-1	2	3	0.67			3	3	2	1	2

[*] For the questionnaire results: 1= don't know/never, 2= once or twice a year, 3= once or twice a month, 4= weekly, 5= daily

[**] Student code indicate (1 or 2 for Google Earth or paper maps)-(pair number)-(individual identity number within that pair)

[#] For methodology, a '1' indicates that the students completed the activity with paper maps and a '2' indicates that the students completed the activity with Google Earth

2-1-2	2	3	0.67			3	3	3	2	4
2-2-1	2	5				4	2	1	1	1
2-2-2	2	5				2	3	2	1	4
2-3-1	2	2				3	2		1	1
2-3-2	2	2				2	2	1	1	2
2-4-1	2	4				2	1	1	1	2
2-5-1	2	2	0.67			3	3	2	1	2
2-5-2	2	2	0.67			1	3	3	1	2
2-6-1	2	3	0.00			3	2	3	1	1
2-6-2	2	3	0.00			3	2	1	1	1
2-7-1	2	2				2	3	4	1	2
2-7-2	2	2				1	1	2	1	1
2-8-1	2	3	1.00			4	2	2	1	2
2-8-2	2	3	1.00			2	1	2	1	1
2-9-1	2	4.5	1.00	0.64	0.36	3	3	2	1	3
2-9-2	2	4.5	1.00	0.64	0.36	4	4	3	1	5
2-10-1	2	2	0.67			1	2	3	1	4
2-10-2	2	2	0.67							
2-11-1	2	1	1.00			2	3	1	3	1
2-11-2	2	1	1.00			1	1	1	1	1
2-12-1	2	4	0.00			3	2	3	1	3
2-12-2	2	4	0.00			3	2	2	1	1
2-13-1	2	4.5	1.00			3	3	3	1	3
2-13-2	2	4.5	1.00			2	3	3	1	4
2-14-1	2	3	1.00	0.00	1.00	4	1	1	1	4
2-14-2	2	3	1.00	0.00	1.00	1	2	1	1	1
2-14-2	2	2.5	1.00	0.56	0.44	3	3	3	1	2
2-15-1	2	2.5	1.00	0.56	0.44	2	2	2	1	1
2-16-1	2	2	1.00			1	2	1	2	2
2-16-2	2	2	1.00			4	1	1	1	1
2-17-1	2	4	1.00	0.33	0.67	5	1	1	1	5
2-17-2	2	4	1.00	0.33	0.67	3	3	3	1	2
2-18-1	2	3	0.75	0.46	0.54	2	3	1	1	4
2-18-2	2	3	0.75	0.46	0.54	1	2	1	1	1
2-19-1	2	3	1.00			5	2	1	1	1
2-19-2	2	3	1.00			3	1	2	1	4