USING EDUCATIONAL TOOLS AND INTEGRATIVE EXPERIENCES VIA GEOVISUALIZATIONS THAT INCORPORATE SPATIAL THINKING, REAL WORLD SCIENCE AND OCEAN LITERACY STANDARDS IN THE CLASSROOM: A CASE STUDY EXAMINED

by

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In Gratitude

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I truly believe *The Journey is the Reward*. And I have been infinitely blessed with rewards.

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Using Educational Tools and Integrative Experiences via Geovisualizations That Incorporate Spatial Thinking, Real World Science and Ocean Literacy Standards in the Classroom: A Case Study Examined

Abstract

The field of geography has been transformed in recent years through the use of spatial tools such as geographic information systems (GIS) satellite and acoustic remote sensing, the global positioning system (GPS), Internet mapping and more. Studying geography and earth science in the digital age now requires a sophisticated and complex integration of concepts that include spatial and temporal aspects (Harrower, et al., 2000). Using the same tools and data sets as earth scientists, students can explore spatial patterns, linkages, trends and processes on a local, regional or global scale. Despite our capabilities and advances, many questions remain about how to use these new geospatial tools and apply representational techniques to problem solving and knowledge construction. Particularly in educational settings, the potential of applying tools and techniques in problem-solving exercises remains largely underutilized. This paper examines the application of multimedia technologies and interactive geovisualizations based on ocean literacy principles in high school curricula to develop spatial thinking and promote geographic literacy. The objectives explored include the advantages of using geovisualizations, how multimedia digital technologies can be utilized in meeting educational standards and what pedagogical goals can be met with use of interactive tools in the classroom. The main findings of this study include improvements in quantitative scores using a testing instrument designed to assess competency in geographic standards and mastery of spatial thinking abilities. The students in this study demonstrated the acquisition of deeper levels of understanding and improvements in comprehension of content related to oceanography, geography and spatial thinking. These results show promise for the use of geovisualizations and real science tools in a multidisciplinary fashion in standards driven curriculum development for the science classroom.

Introduction

Earth science teachers have a multitude of teaching methods, curricular tools and learning modalities to choose from when designing curriculum. These include verbal, oral, and visual presentations, involving static, dynamic or interactive modalities. Examples of verbal message delivery include lectures, reading assignments, equations, and Powerpoint slides narrated by the instructor. Oral presentations usually accompany and complement verbal or visual aids, the most common being a lecture style delivery of information or verbal dissemination of instructions. Visual presentations include models, photographs, aerial images, remotely sensed images, drawings, videos, maps, data-based visualizations, graphs, computer animations and computer models. Curriculum aids such as photographs, paper maps, Powerpoint slides or diagrams are created as static tools that convey or depict a concept of earth science, such as a map documents displaying an ecological theme (Figure 1). This paper considers the use of geovisualizations in educational settings. A geovisualization is broadly defined as a representation of a geographic concept or data set, and 4 distinct types are examined; static, dynamic, interactive mapping software and serious games or animations. An example of a static geovisualization would be a map representing the migratory route of the gray whale along the Pacific Coast of North America (Figure 1).

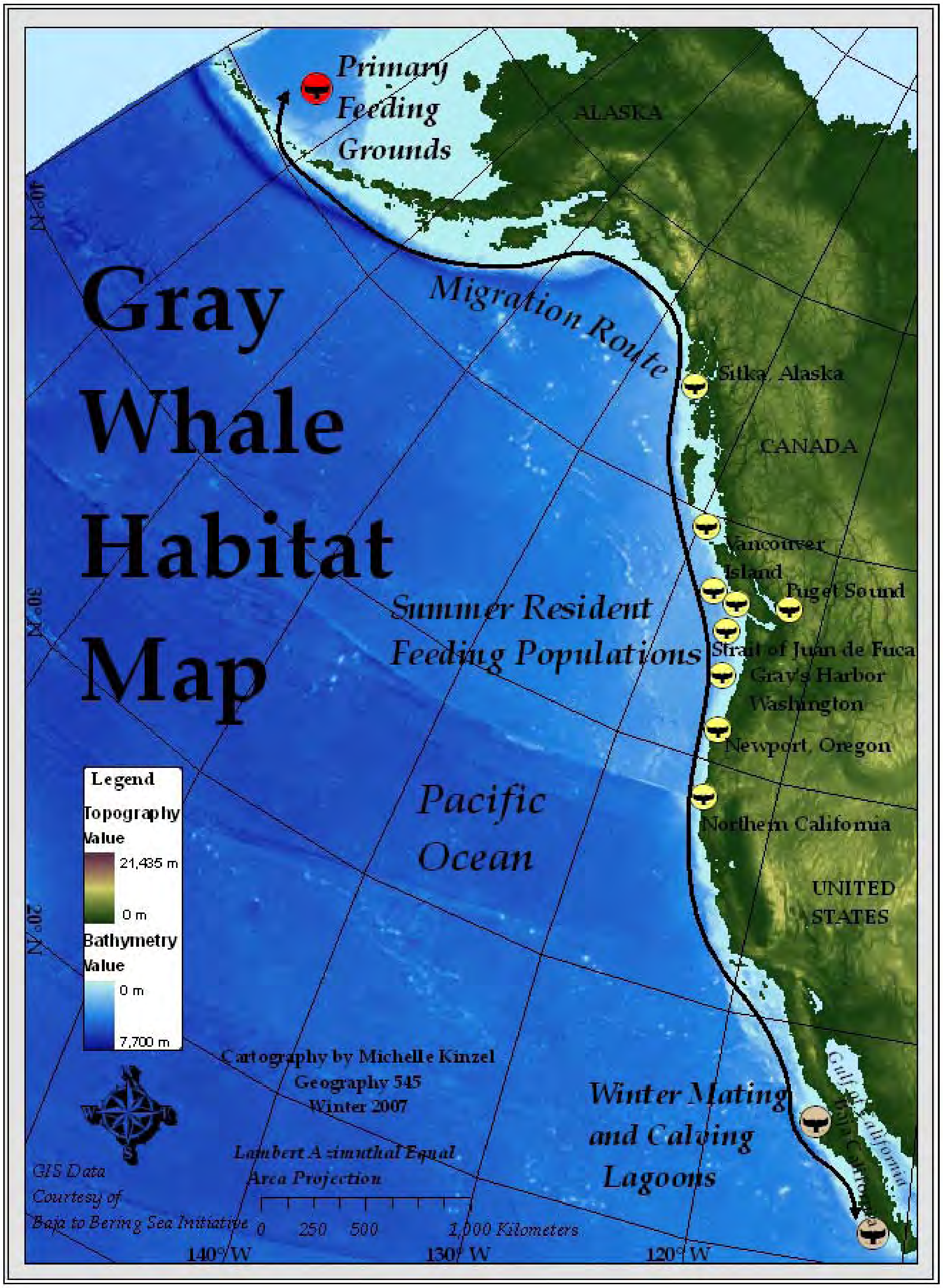


Figure 1. GIS Map representing migratory route of gray whales in North America, an example of a static geovisualization. Created with ArcGIS 9.1.

The term geovisualization, known also now as geovisual analytics, is commonly understood to represent a geographic visualization, and holds various definitions and criterion in different academic circles (Buckley, et al, 2000; MacEachren and Kraak, 1997). MacEachren and Kraak describe "geographic visualizations" as products resulting from linkages among cartography, GIS, and related visual information technologies. The authors also describe geovisualization as both a research focus and a set of tools that hold the promise to change and improve the very fundamental concepts of science and the methods used to explore georeferenced data, the decisions made by society and the way we learn about the world. And they certainly have. The use of mapping tools, internet servers and multimedia has revolutionized the way we experience and explore our world.

For the purposes of this paper, geovisualizations are defined to be the tools and products of geographically referenced datasets, including static maps and diagrams, animations, outputs of mapping software and animated scenes of serious gaming environments. Serious games are an emerging tool, a hybrid of education and fun, and include various types of gaming technology that contain an educational component, namely the integration of educational content into an online or electronic gaming environment (Prensky, 2007). A serious game should be considered more of a simulation than a computer game, with the distinction being that educationally oriented serious games are about objects, concepts and systems and how they behave, while computer games are about a fun experience for the user (Prensky, 2007). Ideally, the most appealing serious games will be fun, but will also contain the pedagogical content necessary to merit use in an educational curriculum.

Dynamic elements common in Earth science include movement with or without student interaction, models that move, GIS maps, video clips, and some computer animations. Typically, these types of tools utilize the highly engaging user interface programmed with movement or dynamic data display to engage the learner in the concept. An example of a dynamic earth science tool is a depth profile created in GeoMapApp, which depicts the bathymetry of the seafloor along a transect as chosen by the user in a graphical output (Figure 2).

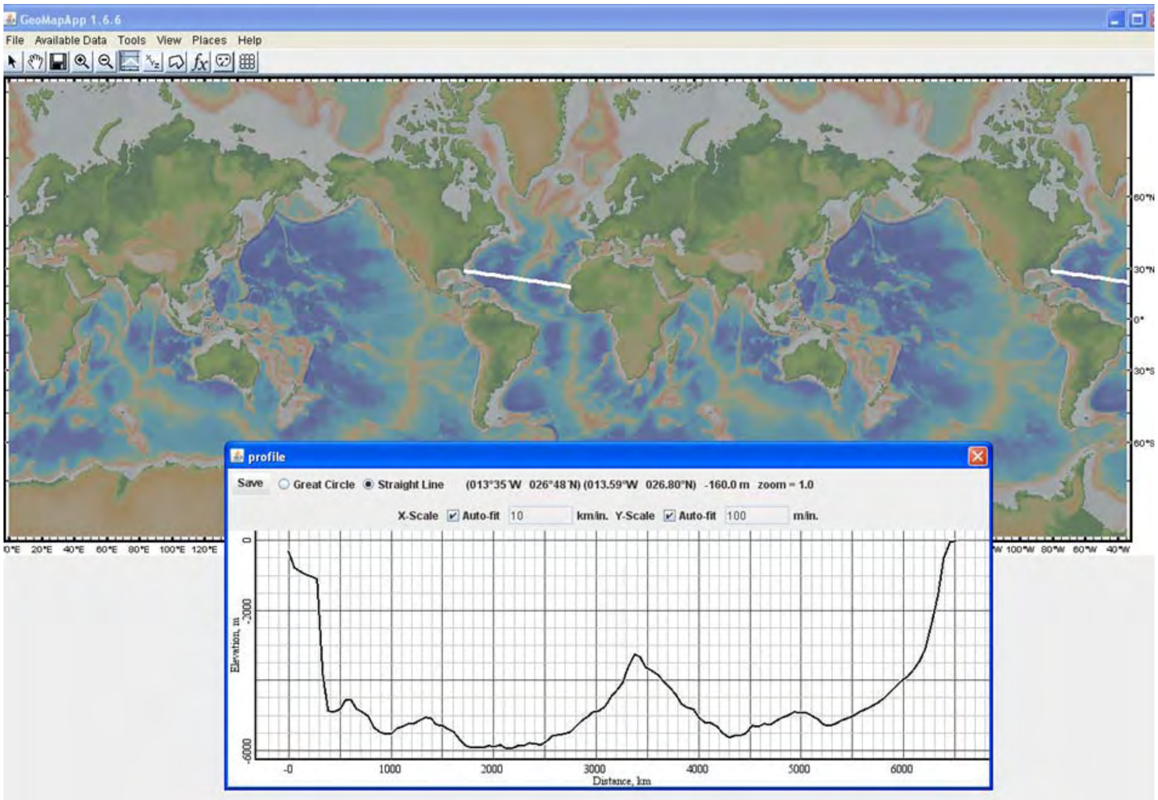


Figure 2. Screen shot from GeoMapApp, showing world geographic map output and profile of seafloor across an imaginary transect line between North America and Africa, an example of a dynamic geovisualization.

GeoMapApp is a data exploration and visualization tool developed at Lamont Doherty Earth Observatory (http://www.geomapapp.org/) that allows access to a variety of data sets within an integrated mapping application (Appendix 1). The most effective tools for engaging students in the learning process are interactive ones, such as geographic information system (GIS) map projects, visualizations, computer models and computer animations that allow the learner to manipulate the environment and outcome of the learning process. These types of tools allow for the highest degree of active learning, a modality of teaching and interacting that places the emphasis on the student. This philosophical approach shifts the educational experience to focus on the activities of the student (Solem, et al., 2009)

Active learning is based upon constructivism theory, which states that learning is a process in which the learner actively constructs knowledge (Riggs and Kimbrough, 2002). The constructivist approach in science education is recognized as a valuable approach for building deep student understanding of scientific content and inquiry (Riggs and Kimbrough, 2002). This type of learning does not occur in lecture only environments, as the students are merely passively listening and transcribing notes, at best. The key to active learning is student participation. Many studies have shown that active participants display superior learning and demonstrate higher levels of comprehension and understanding (McConnell, et al., 2003). Asking students to apply newly acquired knowledge in problem solving has been shown to improve student retention, exam scores and scores on logical thinking assessment (McConnell, et al., 2003). Activities involving active learning span the simple as well as more complex tasks, ranging from multiple choice questions to project based exercises involving multiple class periods (Silberman, 1996). Students using inquiry based learning or active learning must form research questions, develop a methodology, gather and analyze data, draw and report conclusions.

For Earth science teachers, the digital age offers a plethora of spatial tools and techniques for implementing inquiry based activities and active learning into existing curricula. Yet educators are reluctant to embrace the pedagogical shift required to acquire and master the tools of higher technology (Kerski, 2000). Not all technology is complicated or prohibitive and considering the adaptability and variety of pedagogical tools, it becomes clear that the use of geovisualizations is an ideal way to address core Earth science and geography concepts, meet standards based curriculum development goals, incorporate technology standards and engage students in active learning that is engaging and effective. In 2012, technological literacy is slated to become part of the National Assessment of Educational Progress (NAEP) also referred to as the Nation's Report Card (eSchool News, 2008). Students will be required to demonstrate proficiency with technology in 4th, 8th and 12th grades. The No Child Left Behind Act, passed into law in 2002 includes technology goals, requiring students to be technologically literate by the end of 8th grade (Learning Point Associates, 2007). It also includes geography as one of nine key areas of instruction, yet Kimberly Crews, Executive Director for the National Council on Geographic Education states that "With No Child Left Behind, it's geography that is being left behind" speaking to the fact that geography is the only key area of the act not provided with funding (Chicago Tribune, December 2, 2007).

Justification for Research

Skill development is a primary component of any educational process. Recent trends in educational standards have expanded, and are now acknowledging the importance of such non traditional skill sets as geographic literacy, cognitive spatial thinking skills. Proponents of these educational premises assert that in order to achieve a goal of spatial literacy, a literate person will display three characteristics: knowledge of concepts, command over ways of thinking and acting and the development of capabilities (National Research Council, 2006). The National Research Council details three characteristics of a spatially literate student as (1) having the habit of mind to think spatially, (2) practice spatial thinking in an informed way, specifically having well-developed spatial capabilities for using supporting tools and technologies and (3) ability to evaluate spatial data based on the source and using this data to construct and articulate a line of reasoning or point of view in problem solving.

Spatial thinking is not only beneficial to understanding our increasingly digitally represented world through mediums such as Google Earth and Map Servers, but is a useful skill set in a variety of disciplines. The fields of architecture, medicine, physics and biology all rely to some degree on the development and application of concepts of space, adeptness with the tools of representation and the process of reasoning (National Research Council, 2006).

Additionally, there is a recognized need for increased understanding of the oceans, its inhabitants and the effect of oceanic process for life on earth. In 1994, the National Geographic Foundation established a set of standards for ocean literacy that link oceanography with geography and include spatial thinking as a major element of its foundation. The curriculum of choice for meeting most of these objectives is a multidisciplinary fusion of ocean science, geography and social studies. The ultimate message is that all life on Earth arises from, and is dependent upon, oceanic processes. The main objective of the standards matrix is to encourage the development of ocean literate citizens that will become Ocean Stewards in the 21st Century (Geography for Life: National Geographic Standards, 1994).

The central premise of this research paper is that ocean science education should incorporate the latest advances in science and technology with the tools and capabilities of a geovisualization. There is a natural resonance between technological literacy and spatial literacy, and the sharing of technological tools with curricular materials based on spatiotemporal data sets represents an engaging and dynamic means of encouraging concept comprehension and skill development.

The purpose of this case study is to use multimedia tools and real world scientific data sets in the classroom and assess measurable changes in spatial thinking skills and geographic literacy standards. It also seeks to evaluate effectiveness of geovisualizations in an educational setting, changes in spatial thinking skills and level of geographic literacy proficiency among students given the opportunity to explore multimedia tools with guided discovery and open ended class time.

The four primary questions this study addresses are:

1) What advantages are there to using an interactive, immersive geovisualization in the design and implementation of curriculum at the high school level?

2) How can multimedia digital technologies best be utilized in aiding students to achieve the educational standards related to geography, science and technology?

3) What pedagogical issues in secondary school curriculum development can be addressed with the use of interactive, immersive geovisualizations?

4) How does the use of real world scientific data sets enhance educational practices?

Pedagogical Goals

Particularly in educational settings, the potential of applying tools and techniques in problem solving exercises remains largely underutilized (Harrower, 2000). To date, much of the research effort in geovisualization has been directed at an expert level, for individuals who posses high level knowledge of the subject matter, such as the use of ocean color by climatologists. Geovisualizations are also designed for those who work routinely with large and cumbersome data sets, such as statisticians (Harrower, 2000). Digital mapping tools such as Google Earth, GeoMapApp, AEJEE, ArcGIS and ArcExplorer developed under the umbrella of geographic information systems have the potential to revolutionize the traditional Earth Science or Geography curriculum. The potential for harvesting these powerful tools to explore scientific data sets has yet to be tapped. With the increasingly ubiquitous availability of the internet, the time has come for educators to incorporate internet mapping into a variety of subjects, courses and teaching practices. The issues are not centered on limited choices in technological tools, but instead lack of accessibility due to funding or infrastructure and lack of time to implement what is available (Kerski, 2000). Most educators, even those highly motivated to explore new modalities and incorporate the latest technologies struggle under standards based requirements, a schedule deficient in time, and inadequate funding to acquire and maintain cutting edge technologies.

With today's technologically savvy youth, the use of geovisualization offers the potential of creating experiences at a more introductory and educational level, for use in high school curricula. The educational objectives of introducing spatial concepts, promoting spatial learning and achieving geographic literacy among students can be supported by using mapping software, such as GIS applications, incorporating static images and dynamic tools of geovisualizations and integrating serious games into learning units across a multitude of core content subject areas and in diverse learning environments. The most useful and effective means of implementing spatial tools and technologies into a curriculum involve multi task and multi disciplinary activities, that extend beyond a narrow range of subject matter (Cooper, et. al.. 2002; Kerski, 2000; McConnel, et.al., 2003; White and Sims, 1993).

The rapid proliferation of computer technology has improved the options available for many educators of Earth Science and Geography. There are a multitude of visual aids, technologies, software packages and tools that can be integrated into traditional educational practices. The lag time and weak link in the chain is that educators must familiarize themselves with new computer software packages, learn new technological skill sets and rework existing lesson plans to incorporate the new capabilities and spatial products (Bishop and Shroder, 1995).

In a rush to accountability of the No Child Left Behind era and a political climate in public education arenas that often emphasize preparing for standardized testing, teacher evaluations and report cards for schools and districts are used as determinants to levels of funding, social studies at the elementary level are being left behind (Alvarez, 2008). This neglect of basic content areas such as geography and earth science will only magnify throughout the school system. Without solid foundations to build upon, the achievement of geographic literacy becomes increasingly difficult as students progress through the school system. One fundamental feature of geographic literacy is the concept of spatial thinking (National Geography Standards, 1994). Spatial thinking can be considered a 'habit of mind' related to the concepts of space, geospatial tools that represent process and concept, and reasoning processes (National Research Council, 2006).

The concept of spatial thinking is not exclusive to the social sciences, nor is the pedagogy a task solely for geography educators, rather it is important to integrate spatial thinking across the curriculum (Alvarez, 2008). Educators are often overburdened and constrained for time. By integrating activities that foster spatial literacy into a variety of subject areas, such as science and mathematics, educators can teach across the disciplines, and incorporate social studies into existing curricula.

Out of necessity, all too frequently, the main goals for today's classroom sessions are to teach to standards based learning objectives in preparation for standardized testing. The current educational administration in the United States is focused on meeting national and state objectives, which are disproportionately heralded as markers of success within school systems. In order for change to occur, in particular a change that would embrace the digital revolution and encourage or even allow educators to embrace new tools or techniques in their curricula, there must be a means of assessing competencies and mastery of learning objectives related to digital technologies. The standards vary widely among subject areas, grade levels, states, counties and even school districts, but all educational systems are looking towards the effectiveness of tools in meeting standards and teaching the technological skills necessary for students to be successful in the global workforce (eSchool News, 2008). As suggested in Table A1.2 (Appendix 1), geovisualizations can be used to address these complex needs, including standards related to geography. Further consideration of relevant and topical literature on the use of geovisualizations is presented in Appendix 3 of this paper.

Static geovisualizations are the most diverse in terms of applications to standards. Some geographic standards, such as the use of mental maps (Standard #2) only lend themselves to a static geovisualizations such as a drawn map representation (Appendix 2). And some standards are suitable for the use of static geovisualizations such as maps and diagrams, as exemplified by the Standard #6 which emphasizes culture and experience (Appendix 2). Currently, dynamic geovisualizations such as animations are useful mainly for demonstration and skill development. Due to the largely unchangeable nature of a video clip or animation, these tools are not applicable as stand alone instruments of assessment. Mapping software tools such as GeoMapApp or ArcGIS provide the greatest degree of usage in both terms of skill development and assessment. The dynamic nature of mapping software combined with the ability of the instructor to create assessment activities for building and displaying mapping layers make this geovisualization ideal for integration into most curricular plans and objectives. Yet the educational community and those who govern it need research on the effectiveness of these tools, and a cadre of easily accessible and easily implemented tools and resources (Kerski, 2000). Practical applications and testing modules that could be integrated into educational curricula facing pressures of funding issues and time constraints may increase the use of geovisualizations across a broad spectrum of disciplines, grade levels and educational settings. Serious games, while alluring and certainly high on the engagement scale, hold the most promise as skill development tools. Assessment is not prohibited, yet is not as easily accomplished as with the other types of geovisualizations.

Methods and Procedures

School Setting

The setting for this study was two Horticulture classes at a local public high school, Corvallis High School in Corvallis, Oregon. These courses consisted of students in grades nine through twelve, in a course designed to be a science elective, and generally comprised of lower than average academic performing students. These particular students were not chosen at random, but were the ideal choice for a pilot study to examine changes in spatial thinking and assessment of geographic literacy standards. The main reasons for conducting the pilot study at this particular school were the flexibility and interest of the science teacher, the structure of the daily class time blocks (90 minutes in duration), the ongoing field work that included a mapping component in existence at the time of the initiation of the study, and the class subject outside the main focus of the GeoMapApp computer sessions and assessment questions, bathymetry and seafloor mapping. The focus of this study is the use of geovisualizations, mapping technologies, and scientific data sets in education, and not necessarily one of applications of the scientific principles. The topic of the assessments and GeoMapApp computer sessions was seafloor bathymetry, and for the reasons described above, it was not deemed necessary to assess a group of students studying Geography, Oceanography or Marine Science. In fact, students a class outside of these areas was suited to the assessment, as the terminology and scientific principles would be novel to the student subjects, and a more accurate assessment of changes or improvements on the testing instrument would reflect effects of the classroom time using GeoMapApp.

Data Sets

Not all data sets are created equal in relation to uses in a geovisualization. The best fit for GIS tools is with data that is less tangible and more difficult to observe directly, such as cultural patterns, bathymetry or ground water contamination (Solem, et al., 2009). Data sets with complex patterns or connections often work well with geovisualizations. GIS education focuses on spatial concepts and theoretical considerations for the representation of spatial data (Carlson, 2007). Scientific data with temporal and spatial components are ideally suited to a geovisualization, such as displaying the movement of a tsunami across an ocean basin and into low lying coastal areas. While animations capture time series data in an easy to follow and organized fashion, changes over time can also be represented with interactive mapping tools (Andrienko and Andrienko, 1999). Data sets that have spatial coincidence, for example the location of satellite tagged whales and the continental shelf along the coast display especially well in a GIS. The ability to overlay graphical representations makes a GIS ideally suited to studying processes and concepts involving 2 or more sets of data, as shown by the map layout in Figure 3.

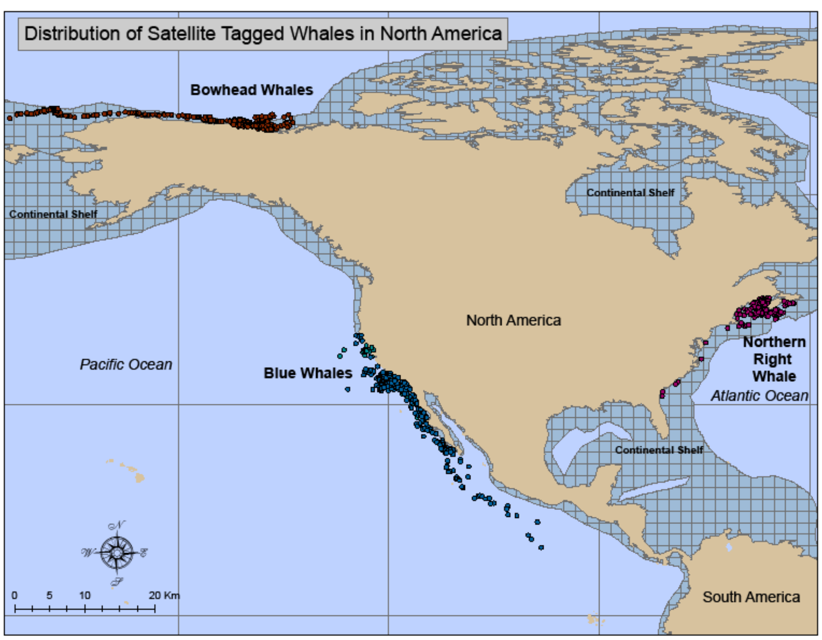


Figure 3. GIS created map showing distribution of 3 species of whales, Bowhead, Blue and Northern Right whales, as determined from satellite telemetry tags, and their spatial relation to the continental shelf and coastal areas of North America. Created with ArcGIS 9.1. Marine mammal data courtesy of Marine Mammal Institute, OSU, http://mmi.oregonstate.edu/.

Geovisualization Tools Used

In this study, participants worked with software packages and hand held GPS units to explore geospatial concepts. Two software packages were used, GeoMapApp and ArcGIS 9.1. Both software platforms are categorized as GIS, or Geographic Information Systems. A GIS is an integrated collection of both computer software and datasets used to view and manage information about geographic locations. A GIS is also capable of performing spatial analysis, modeling spatial processes, and providing a virtual framework for gathering and organizing spatial data and related information for display and analysis (ESRI Website, www.esri.com last accessed November 30, 2008).

ArcGIS is an integrated collection of GIS software products, and provides an industry standard based platform for spatial analysis, data management and mapping. ArcGIS is founded upon key interoperability and Web computing concepts. Environmental System Research Institute, ESRI, is the commercial producer of ArcGIS, aligns to the specifications and standards of the Open Geospatial Consortium, Inc. (OGC), as well as those related to ISO, W3C, ANSI, and CEN. ArcGIS, in comparison to GeoMapApp, represents a more advanced, industrial strength technological platform. The minimum system requirements for the most basic of ArcGIS product call for 1 GB of RAM, a 1.6 GHz Processor and a PC-Intel platform running Windows Vista, Windows 2000 or Windows XP. The capabilities of this software are much more extensive and robust than GeoMapApp, and include mapping, advanced cartography, data support and interoperability, data editing, raster editing and vectorization, geoprocessing, modeling. In addition, there are hundreds of extensions and tools that work in conjunction with ArcGIS software to enhance the geospatial needs of numerous sectors of industry and academia. ArcGIS, in comparison to GeoMapApp, represents a more advanced, industrial strength technological platform.

Student Activities

A total of six 90 minute classroom sessions were dedicated to the introduction of GIS and GPS technology, field data collection and computer mapping. This included, two sessions dedicated to learning basic geospatial concepts and GPS unit functionality, as well as collecting data at a local watershed, Dixon Creek, one session using the ArcGIS software, and three sessions using the GeoMapApp software.

The ArcGIS 9.1 sessions were conducted off the main high school campus, in the Digital Earth Classroom at Oregon State University. For ease of facilitation and due to time constraints, much of the data preparation was performed by an experienced GIS user. The teaching portion of the activity focused on the following functions: basic navigation, adding georeferenced data collected from a hand held Garmin eTrex GPS Unit, creating a map layout and basic cartographic map element manipulation; adding text, adding a map title, adding a North Arrow, and adding a scale bar (Figure 4 and 5).

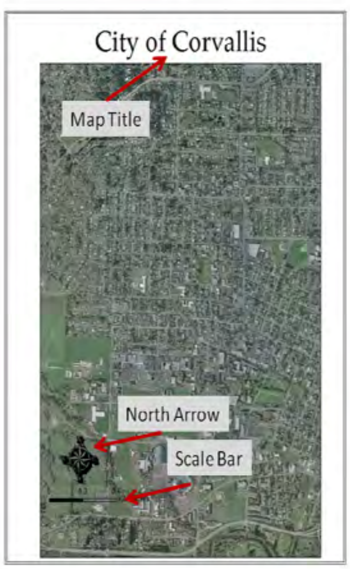


Figure 4. Map Layout showing map elements used in ArcGIS 9.1 sessions.

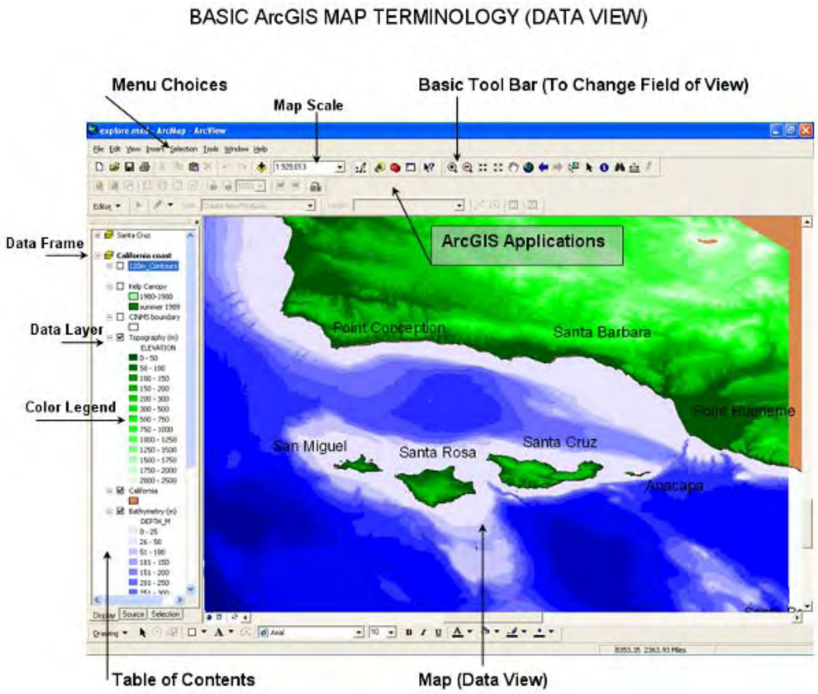


Figure 5. Screenshot from an ArcMap 9.1 session, showing the Basic Tool Bar (for basic navigation) and main components of a map document.

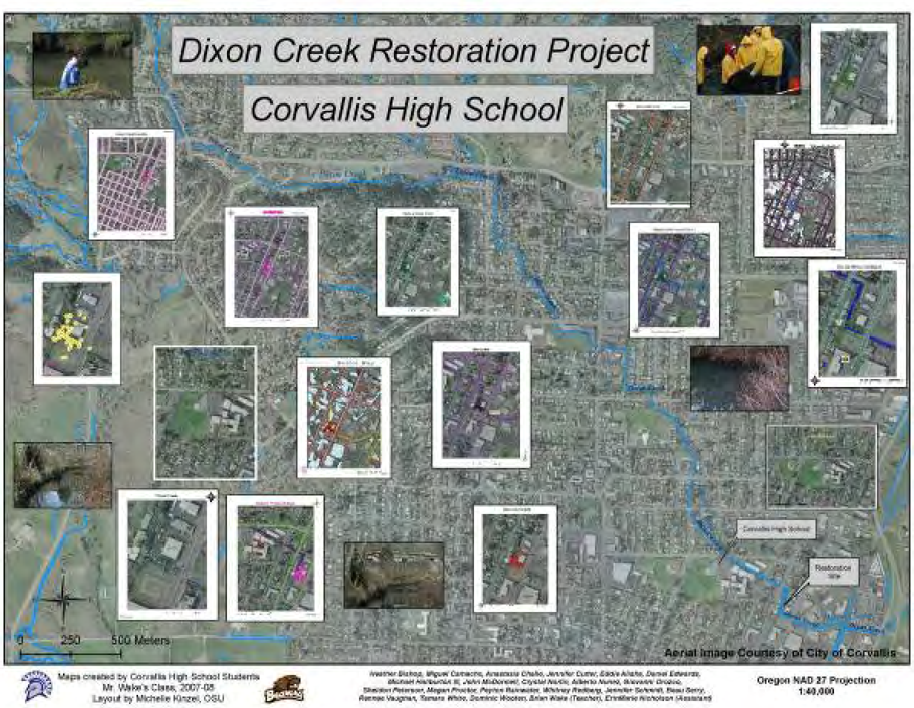


Figure 6. Poster (Actual Size = 44" x 34") collage of student created map layouts, representing successful mastery of ArcGIS basic navigation and cartography skills.

Each student was coached in the basic functionality of the ArcGIS 9.1 software as necessary to create a map document and printable map with data imported from a file, in approximately 15 minutes. The participants were then allowed 25 minutes to create a unique and personalized layout of data collected as a group at the field site for the class, Dixon Creek in Corvallis, Oregon. Geospatial data, including an aerial photograph, street layers, hydrology layers and transportation layers were provided by the City of Corvallis Public Works/GIS Department. Students created ArcGIS map documents (.mxd files) and Adobe Acrobat pdf map layouts using data they collected in the field using the hand held e-Trex Garmin GPS units and ArcGIS 9.1 software, and data provided by the City of Corvallis GIS Public Works Department. All map layouts were saved as Adobe Acrobat files, and compiled into a poster sized print out for display of group work and review by participants and project supporters (Figure 6).

The GeoMapApp software package was used for three classroom sessions of 90 minutes in duration. The first session included an introduction to the software and basic skill building, including map navigation, creating profiles and adding data from folders (Appendix 1). Students worked independently to practice tools and functionality of the software, and to complete a worksheet (Appendix 4). The second session included guided discovery activities, building upon and reinforcing the skills introduced in the first session. A second worksheet was given to the students to encourage skill development and practice (Appendix 5). The third and final session using GeoMapApp involved pairs of students working together on an open ended scenario activity that combined the learned and practiced skills with decision making and inquiry based science (Appendix 6).

To assess the effectiveness of using geovisualizations in meeting leaning objectives and increasing competency in grade appropriate geography standards, a testing instrument was created (Appendix 7). The instrument was created to measure achievement and performance as a result of the classroom sessions, and was structured to assess process skills, by demonstrating knowledge in performing a task (Bednarz, 2000a; Linn and Gronlund, 1995). The testing events occurred before and after three computer based, hands-on inquiry lessons using the computer software GeoMapApp. Students explored geographic data sets, oceanographic data sets and biological data on whale movements during guided instruction that initially emphasized technological proficiency with the multimedia tool GeoMapApp and progressed to an open ended scenario based activity that required the students to work in pairs on an inquiry based lesson evaluating the most suitable locations for Marine Protected Areas along the Pacific coast of North America (Appendix 6). Open ended time was scheduled into the sessions to allow for reflections, discussion and collaborative problem solving using the tools and concepts learned. Research suggests that when students have time for reflections and discussion of a topic, they perform better and retain more knowledge (McKeachie, 1994). A detailed summary of student activities by day and topic is presented in Appendix 9.

Assessments

Students were given a pre and post assessment test immediately before and after the three, 90 minute computer activities using GeoMapApp. The pre assessments had questionnaires assessing the students to report and rate their experiences and interest levels with geospatial tools and computer technologies, including computer mapping, GPS Units, Google Earth, video games and cell phones. The post assessments were also preface with a questionnaire, asking students to report on their interest level in the cadre of activities they participated in, including geocaching, using GPS in field work at Dixon Creek, making maps with ArcGIS 9.1 software and using GeoMapApp software to explore bathymetric data. Students were given open ended questions to self report what they learned the most and least from (which activity). Permission to use the testing instrument and collect data from the students was granted by the Oregon State University Institutional Review Board in May 2008 and letters of consent and assent were completed by all students and their parents or guardians (Appendix 10; Appendix 11).

The assessments were paper and pencil activities, with map graphics, bathymetry profile graphics, Google Earth images and figures representing bathymetric features. The pre assessment consisted of 28 questions covering spatial analysis, map interpretation, graph interpretation and mathematical skills (Appendix 7). Students were not allowed access to any resources during the assessment, and given a time limit of 45 minutes to complete all the questions. The order of the questions was designed to begin with relatively simple questions, proceeding to more difficult questions, and randomly presenting map interpretation, graphic interpretation and spatial analysis questions.

The analyses of the quantitative portions of the assessments were performed to test the following hypotheses:

1. There is no difference in the pre assessment and post assessment scores on questions relating to map interpretation.
2. There is no difference in the pre assessment and post assessment scores on questions relating to graph interpretation.
3. There is no difference in the pre assessment and post assessment scores on all quantitative questions combined.

The quantitative portions of the assessments were scored and all data was analyzed using paired t-tests with the statistical software package S-Plus 8.

The analysis of the qualitative portions of the assessments were evaluated in terms of the hypothesis that the students would improve their demonstration of standards based responses in alignment with spatial thinking, National Geography Standards appropriate for grades 9-12, and National Educational Technology Standards for Students. It was expected that students would increase their use of terms characteristic of one or more modes of spatial thinking as described by Gersmehl and Gersmehl, 2007. It was expected that evidence of standards mastery as well as proficiency in spatial thinking would increase from pre to post assessment events. To examine these ideas, Questions 10-12 of the assessment (Figure 7) were evaluated and scored for responses in the following categories:

Spatial Thinking Modes

1) Hierarchy; nested areas of different sizes
2) Proximity; Location is close to…

3) Pattern; Non random arrangement of geographic features

Geographic Description

4) Absolute Location – Latitude/Longitude values

5) Relative Location – Map Position; 2 inches left of Baja California Coast

6) Relative Location – General Scaling; ½ way from top of map

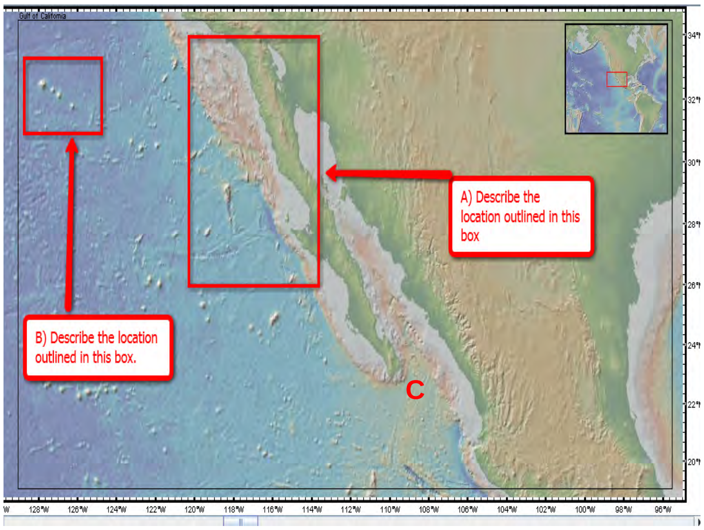
7) Geographic Features; coast, shoreline, land, water, seamount, mountain, etc.

8) Absolute Location - Geographic Names Other

9) Map Color

10) I Don’t Know/Blank

11) Inference; blue whale habitat or reserve



Use this image to answer parts A, B and C below.

Question 10. A) Describe the location outlined in box A. List as many features and geographical descriptions as you can.

Question 11. B) Describe the location outlined in box B. List as many features and geographical descriptions as you can.

Question 12. C) Describe the location represented by the letter C.

Figure 7. Pre and Post Assessment Questions 10-12. Open ended, map interpretation questions used to assess changes in spatial thinking modes and alignment with National Geographic and Technological Standards.

Results

Analysis of Quantitative Questions

Box plots and student t-test results are provided below for the comparison of pre and post assessment scores. The questions were analyzed for differences in pre and post assessment scores. As detailed in Table 1, questions were grouped according to categories, or pedagogical skills sets. Overall, the box plots (Figures 8 through 13) and the reported means (Table 1) indicated a trend towards an improvement in scores between the pre and post assessments. The results indicate that students benefited from the instructional activities and performed better on post tests. Statistically, the evidence is moderately conclusive for the comparisons of pre and post assessments for the map interpretation questions ($p < .05$), and suggestive, but not conclusive for all questions and all participants combined ($p \approx .10$). There was no evidence of a difference in mean scores of male versus female assessments in either pre or post testing (Figure 12 and Figure 13).

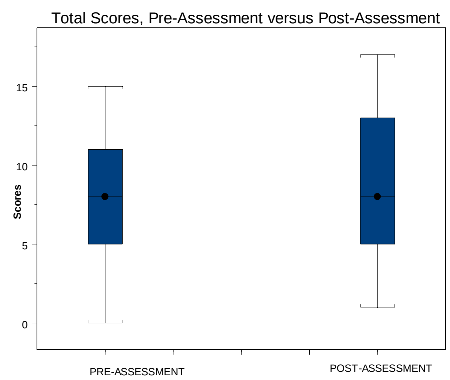


Figure 8. Box plot graphic representing comparison of pre and post assessment scores on all quantitative questions combined.

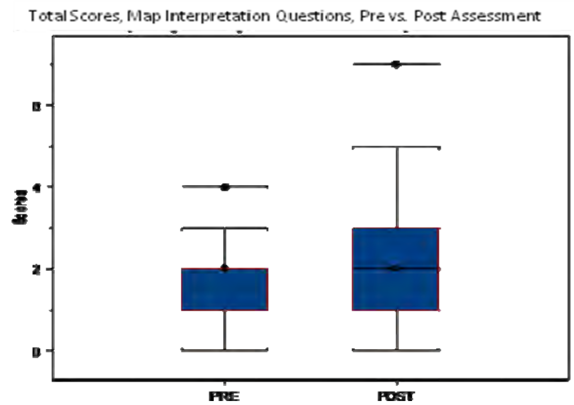


Figure 9. Box plot graphic representing comparison of pre and post assessment Scores for all participants combined for quantitative questions related to map interpretation.

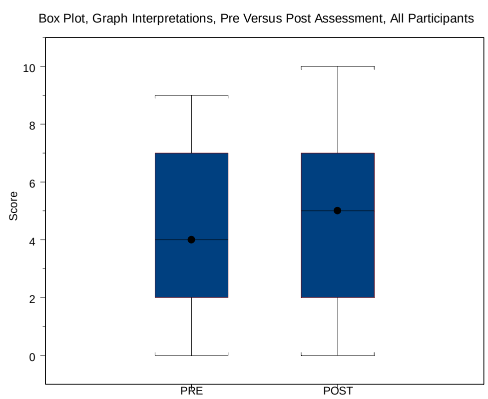


Figure 10. Box plot graphic representing comparison of pre and post assessment scores of quantitative questions related to graph interpretation for all participants combined.

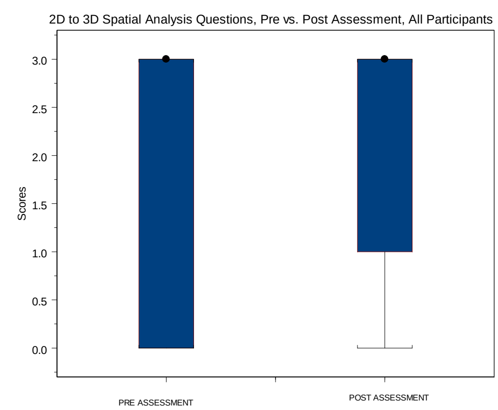


Figure 11. Box plot graphic representing comparison of pre and post assessment scores for quantitative questions related to spatial analysis for all participants combined.

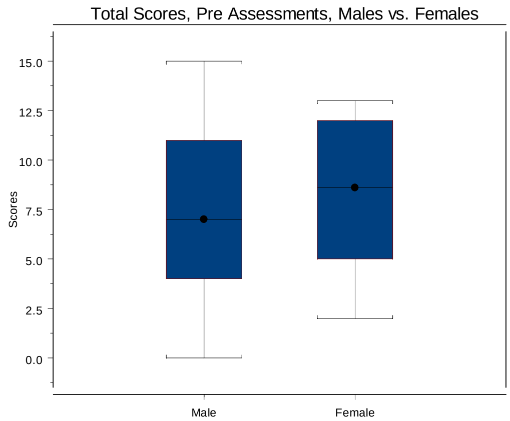


Figure 12. Box plot graphic representing comparison of pre assessment scores of males and females for all quantitative questions combined.

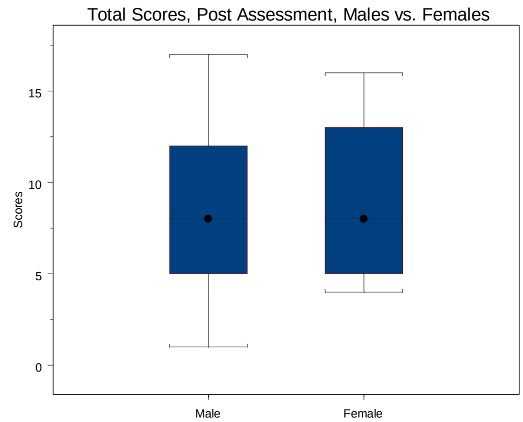


Figure 13. Box plot graphic representing comparison of post assessment scores of males and females for all quantitative questions combined.

Table 1. Table of Statistical Results of Pre and Post Assessment Score Analysis. Means ± 1 SD are reported for Pre Assessment, Post Assessment and Change in Mean Scores. P-vales are reported based on Student t-test analysis as determined using S-Plus Statistical Package. *Questions 2 and 13-15 were combined and analyzed under the category of Map Interpretation Skills. † Questions 3-9 and 20-23 were combined and analyzed statistically under the category of Graph Interpretation Skills.

Question Number ***Pedagogical Skill Set***	**PRE ASSESSMENT**	**POST ASSESSMENT**	**Change in Mean Scores**	**Student t-test paired means**
2. Estimate Slope Across Contour Lines of Seafloor *Math and Map Interpretation**	0.296 ± 0.465	0.444 ± 0.934	0.222 ± 1.086	t = -2.209, df = 26 p-value = 0.0362
3-9. Profile Across Atlantic Ocean *Graph Interpretation*†	2.481 ± 1.55	2.593 ± 1.67	0.444 ± 0.641	t = -0.9208, df = 26 p-value = 0.3656
13-15. Seafloor Bathymetry Visual Graphic *Map Interpretation**	1.480 ± 0.802	1.926 ± 0.829	0.444 ± 0.641	t = -2.209, df = 26 p-value = 0.0362
16-18. 2D → 3D *Object Representation, Spatial Thinking*	2.000 ± 1.359	2.111 ± 1.22	0.111 ± 1.396	t = -0.4136, df = 26 p-value = 0.6826

20-23. GeoMapApp Profiles *Graph Interpretation*†	1.667 ± 1.664	1.889 ± 1.423	0.222 ± 1.188	t = -0.9208, df = 26 p-value = 0.3656
All Quantitative Questions, Combined Scores	7.815 ± 4.077	8.778 ± 4.326	0.963 ± 3.107	t = 1.6105, df = 26 p value = 0.1194
All Quantitative Questions, Combined Scores, Females vs. Males	t = -0.7997, df = 26, p-value = 0.4311	t = 0.0211, df = 26, p-value = 0.9833		

Interpretation of Qualitative Questions

The evaluation of the qualitative questions (10-12) are displayed in the bar graphs of Figures 14-19, showing combined scores for all participants combined, as well as grouping by gender to assess differences in scores between female and males. All individual pre and post assessments included responses that met the criterion for Category # 7, Geographic Features. This was expected, as the wording of the question prompted the students to list geographic features and descriptions. Of the possible spatial thinking categories, hierarchy, proximity and pattern, only hierarchy and proximity answers were provided. None of the participants reported patterns, such as chains of seamounts or other geographic features in a pattern. There was a slight increase in answers that qualified as proximity (Category #2) and absolute location, geographic names (Category #8).

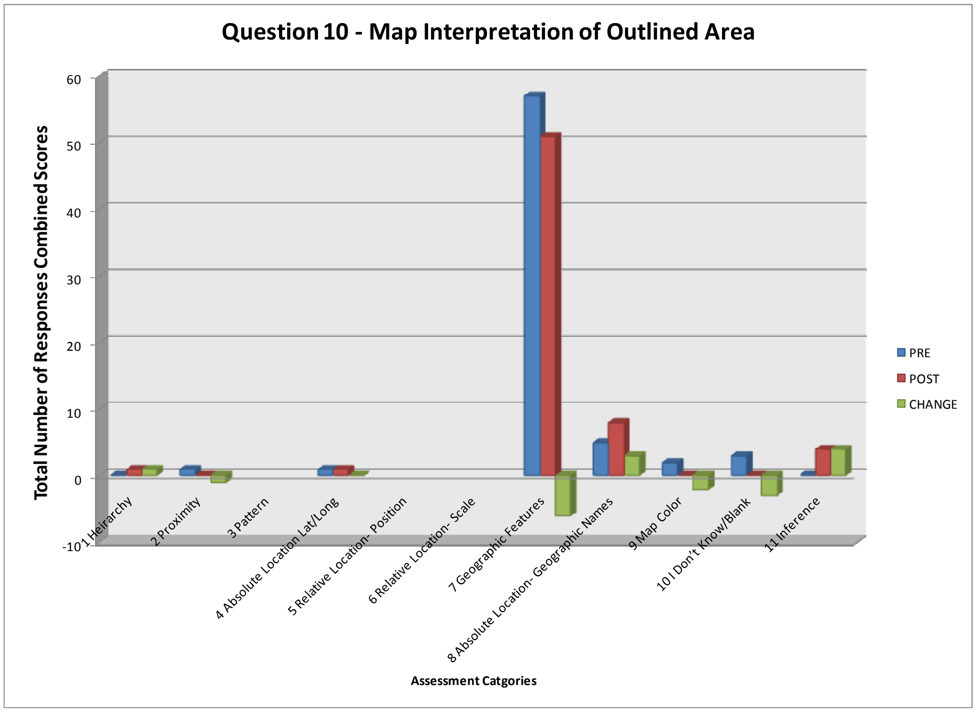


Figure 14. Scored Responses For Qualitative Question Number 10, Map Interpretation of Outlined Area, All Scores Combined.

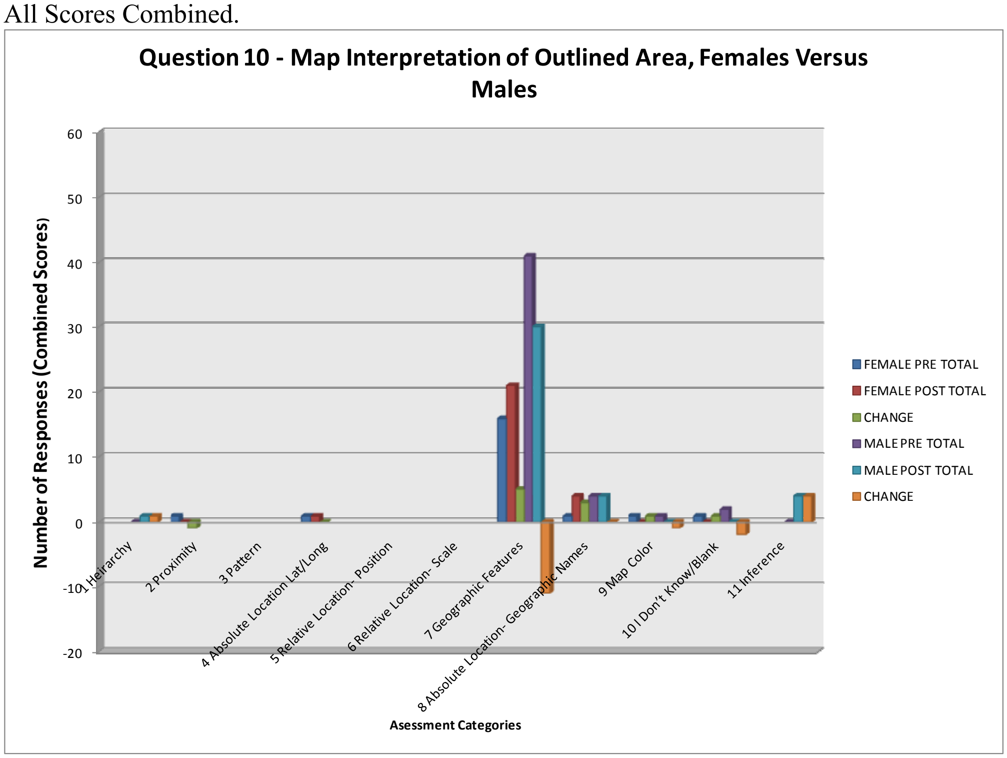


Figure 15. Scored Responses For Qualitative Question Number 10, Map Interpretation of Outlined Area, Females versus Males.

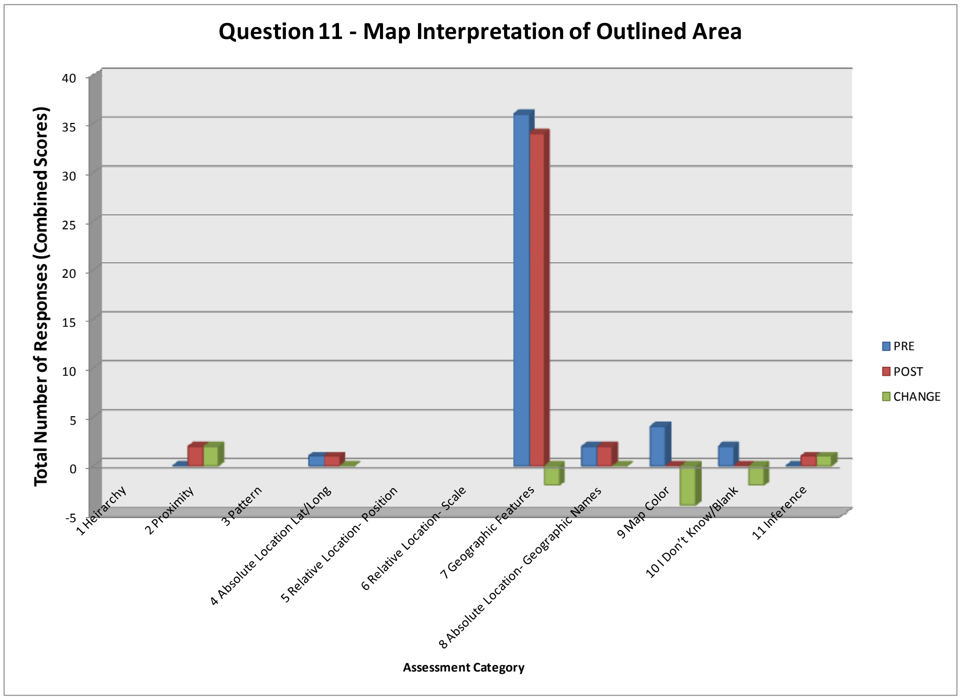


Figure 16. Scored Responses For Qualitative Question Number 11, Map Interpretation of Outlined Area,All Scores Combined, Pre and Post Assessment.

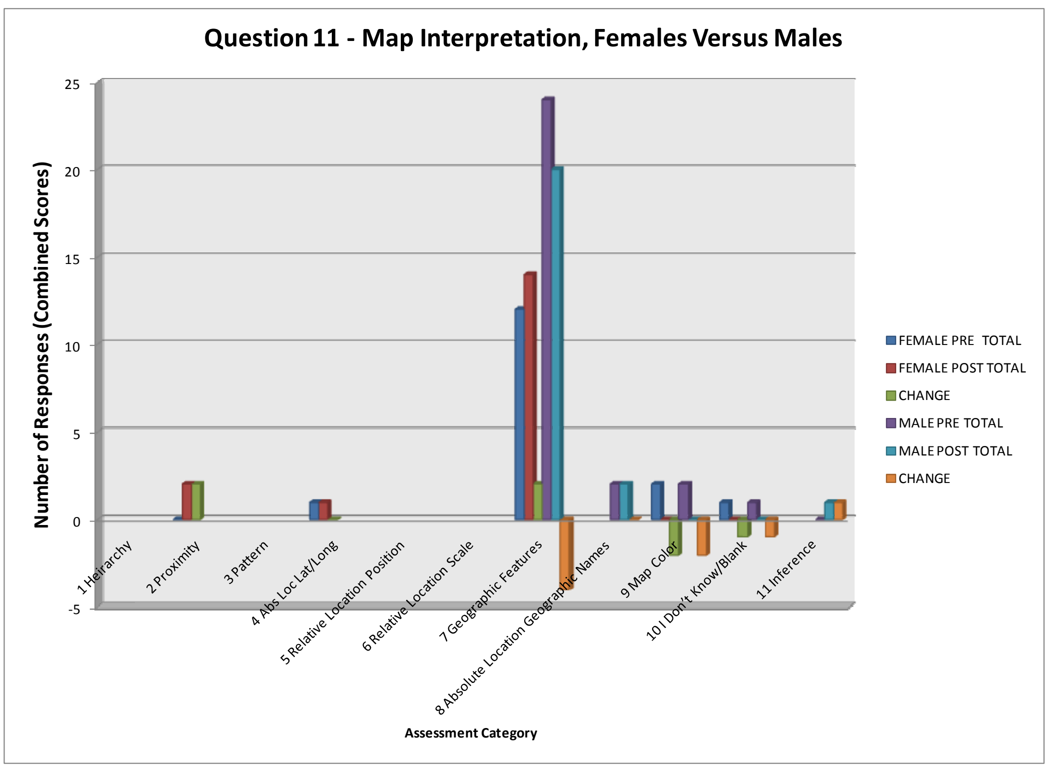


Figure 17. Scored Responses For Qualitative Question Number 11, Map Interpretation of Outlined Area, Females versus Males.

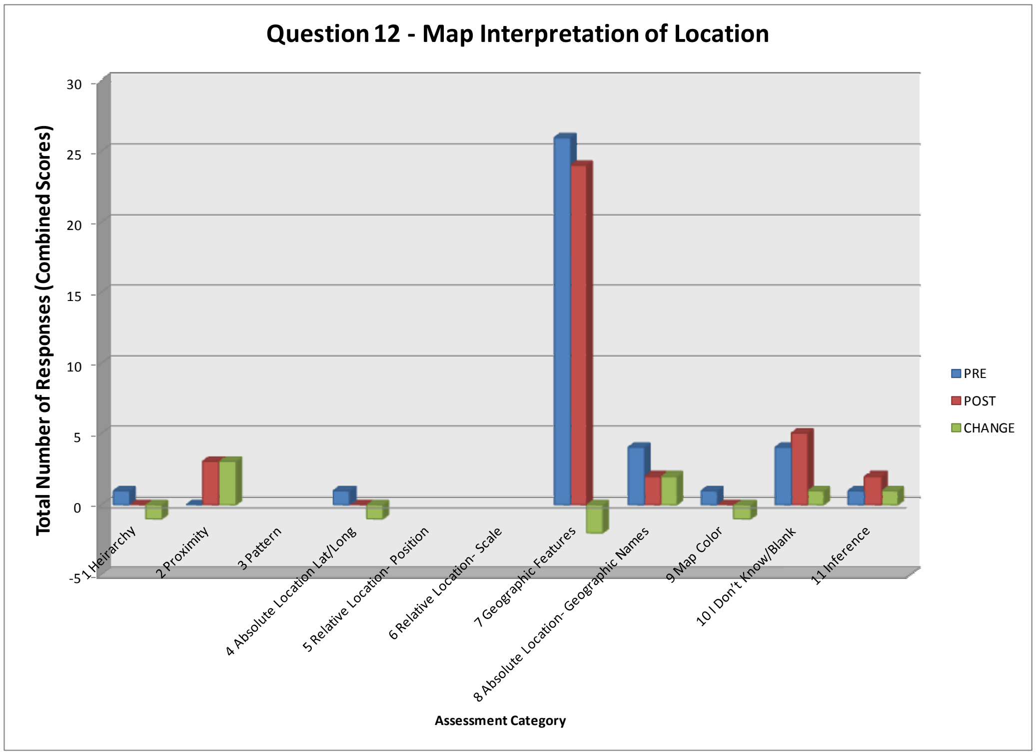


Figure 18. Scored Responses For Qualitative Question Number 12, Map Interpretation of Location, All Scores Combined.

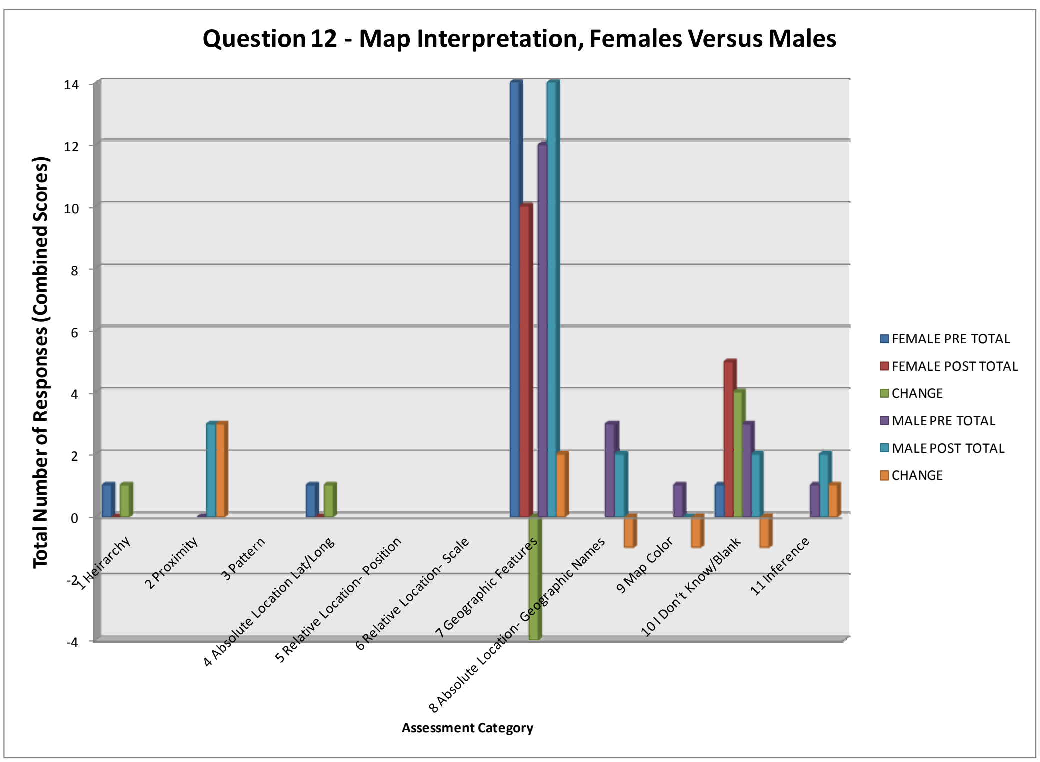


Figure 19. Scored Responses For Qualitative Question Number 12, Map Interpretation of Location, Females versus Males.

In asking the students to self rate the activities, two general areas were approached, their likes and dislikes as well as what they learned the most and least from among the activities (Table 2). The students' top three responses are reported. The most popular answers indicate that the students liked using computers and computer mapping, and learned the most from the GeoMapApp program, and using technology (i.e., hand-held GPS units). The student's dislikes were related to computer issues, including crashing systems and slow response times of the GeoMapApp server.

Table 2. Student comments on the use of GeoMapApp, ArcGIS Mapping Software and hand held GPS units.

What students liked most	What students learned most from
1. Using Computers, Computer Maps	1. GeoMapApp
2. Where whales are found	2. GPS Units
3. Where seamounts and underwater structures are located	3. Calculating slopes
What students liked least	**What students learned least from**
1. Computer problems	1. Geocache
2. Doing math (slope calculations)	2. Computer, indoor activities
3. Not enough time	3. GeoMapApp

Discussion

A recent survey from the Pew Internet & American Life Project, highlights important implications for 21st century learning. The survey, performed in November 2007, reported the results of telephone interviews of 1,102 students from ages 12 to 17 (eSchool News, November/December 2008). The results indicate that while American young people don't all play the same video games, nearly all of them, boys and girls, play video games, even those without access to a home computer. The respondents indicated they utilized gaming consoles in the absence of a home computer system. 97% of the survey participants play video games, 99% of boys and 94% of girls, with little difference in percentages among differing racial, ethnic and socioeconomic groups. Not only is gaming popular among this age demographic, but they play often, half of the survey participants indicating they had played video games the day before (eSchool News, November/December 2008).

The participants in this case study conducted at Corvallis High School reported that they also played video games, and played them frequently. 76% of the students indicated they played video games at least once a week, and 16% claim they play video games daily. Of note, all of the respondents that claimed to play video games daily, all were males (5 of 31) while none of the girls claimed to play video games daily, with most of the girls (6 of 11) reporting that they never played video games, and 4 of 11 girls indicating they played video games once per week. Nearly half, 46% of the participants play video games 1-2 hours/week, with 7% claiming they play more than 8 hours per week.

The participants had a rather limited exposure to other geospatial technologies, including GIS mapping software and GPS technology. On the pre assessment survey (Appendix 8) the participants were asked to report the frequency of using GPS units, and whether or not they had used computer mapping software. All but one of the students reported having used GPS Units at least 1-2 times, and this was expected, as there were 2 group activities that used GPS units, the geocache around campus and the field work at Dixon Creek prior to the survey. 46% of the participants indicated that they had used GPS units outside of the scope of the case study, indicating they had prior experience with this technology. One student reported having used a GPS unit 50 times, without doubt an active participant in the sport of geocaching. All of the students, except for four who were absent during the ArcGIS 9.1 classroom session, had used at least one mapping software prior to the GeoMapApp work, yet 18 of the 32 participants reported that they had not used other mapping software. The other students reported using ArcGIS, Google Earth or EcoMaps.

The results of the pre assessment and post assessment comparison show trends of improvement, indicative of positive shifts in certain areas of the students' understanding of seafloor topography; seamounts, ridges, basins and bathymetry; comprehension of spatial representation of data with a geographic component in a static geovisualization; map interpretation skills, graph interpretation skills and spatial thinking skill sets.
The box plots (Figures 8 through 13) indicate that the overall trend in this case study was an increase in scores between pre and post assessment in all quantitative aspects assessed with the testing instrument. Durbin (2002) examined the use of computers and the Internet as a presentation tool in a college level Geosciences course to convey content

and found improvements of as much as 23% increase in exam scores and 11% in comprehensive final scores. He cited that fewer students failed, and the student work submitted was presented in a more ordered and organized fashion via technological enhancements (Durbin, 2000). Durbin's study concluded that this represented conclusive evidence that computers were indeed beneficial as a tool for learning and retaining information related to geovisualizations, in large part due to the benefit of allowing the students access to extended exposure. In other words, having the ability to view and interact with the geovisualizations beyond the short time span of presentation in a lecture situation was highly beneficial. Interacting with a program such as GeoMapApp, as the students in this case study did, allows for a more constructivist approach to the learning process, encouraging the students to develop deeper levels of understanding and higher levels of comprehension of the mapping and oceanographic concepts introduced.

While the statistical analyses performed, as represented by box plots (Figures 8-13) and results of the student t-tests (Table 1) indicate that there is evidence of a positive change in scores between the map interpretation questions and overall combined quantitative questions, for the pre and post assessment phases of the case study, these results must be interpreted with caution. This case study does not represent a truly scientific randomized experiment. The school and classes were not chosen in a truly randomized fashion, and there was no assessment of a control group. In a truly quantitative sense, this study is classified as an observation study (Ramsey and Schafer, 1997). The caveat with observational studies is that confounding variables, identifiable or not, may be responsible for observed differences. In the case of the high school students participating in the teaching activities of this six day study, those with more experience and comfort with technological applications and computers may have had a distinct advantage. Also, the assessment responses indicated that some of the students had more experience with geography, as in the case of student # 751 who reported absolute geographic information on Questions 10 and 11. When prompted to describe the geographic features in a prescribed area on a map layout, the student noted a very precise location, citing also the importance of reporting latitude and longitude in the interpretation of the map area shown in the diagram. This student was the only one reporting this information. This could indicate a prior experience with geography, but due to the nature of the anonymity and pre and post assessment testing, the students were not individually interviewed, so it is not possible to determine this possibility. Another student, #487, listed 15 distinct geographical feature types for Question 10, an area that included the Baja Peninsula and bathymetry of the nearby coastal Pacific Ocean. The student's' response included terminology such as "peninsula", "continental shelf", "continental rise", "continental slope", and "open ocean". An interesting result was the decrease in the total number of geographic features listed between pre and post assessments. In all of the qualitative Questions 10-12, all groups of participants, with the exception of males on Question 12 listed fewer total numbers of geographic features in the post versus the pre assessment. This could be due to a number of factors, but is most likely indicative of the fact that during the GeoMapApp sessions, much attention was given to analyzing profiles of seamounts in the same area depicted in the assessment graphic, the Pacific coastal area of Baja California, Mexico (Figure 7). Nearly all of the students identified the features within the outlined areas (e.g., Question 11 as "seamounts" or "seamount chain" in the post assessments. Some students replaced a long list of features with these terms, as they could quickly identify the familiar features of a seamount in the maps after working through the classroom activities that centered on the seamount. Once the students had been introduced to these terms, they had a new frame of reference for identifying the features on the map that they did not possess before the classroom activities.

There was a slight increase in the proximity descriptions as well as the absolute locations or geographic names in post testing. This is indicative of an increase in vocabulary, a more well developed sense of spatial thinking and recognition of the area depicted in the assessment graphic, the Baja California peninsula and surrounding Pacific coastal waters (Figure 7). After spending three classroom sessions viewing and exploring the bathymetry of this region, the students had an expanded frame of reference for this particular location in the world, and were able to be more specific in the post assessment in terms of place based geographical references as well as proximity of the features in the diagram (e.g., providing responses such as "close to Mexico", "near the Baja peninsula").

Another noteworthy response on the pre assessment was the inclusion of a description by student #628 of the darker colors representing deeper ocean water and the contour lines as indicative of slope, a topic that was discussed during the GeoMapApp computer sessions, but was completely unexpected in the pre-assessment. In planning discussions with the students and the teacher, there did not appear to be any background or educational experience with contour maps or bathymetric data sets. Some students could have had exposure to contour maps in the course of their education, but it was not a given and had not been covered in this particular course prior to this case study.

Overall, the students reported positive comments related to the activities of the case study, including the GPS technology and practice, field work at Dixon Creek, map making session using ArcGIS9 and exercises using GeoMapApp (Table 2). The post assessment questionnaires (Appendix 8) asked students to self rate their enjoyment levels as well as report what they learned the most from. The answers indicate that the students enjoyed the use of computers, novel and cutting edge technologies, and participating in activities that were outside of their expected classroom routines. The students indicated that they learned the most from the technology, GeoMapApp and hand-held GPS units, as well as the slope calculations using the Distance profile tool and resultant graphical outputs in GeoMapApp. It is interesting to note that some students gave diametrically opposed rankings of the usefulness of GeoMapApp as a teaching tool, indicating they learned the least from this activity.

To categorize this study as observational is not to say the results have no value, nor should they be dismissed. As Kerski (2000) states, empirical evidence is necessary to establish whether GIS tools can substantiate their claims in educational arenas, and whether a GIS can enhance the acquisition of geographic skills and knowledge. And empirical evidence is broadly considered within the context of scientific research to be evidence from observations, originating in or based on observation or experience, capable of being verified or disproved (Montello and Sutton, 2006). Thus, the results of this study are potentially useful to a myriad of communities, notably the growing geospatial educators and academics interested in the application of geospatial technologies and standards in K-12 education.

Microsoft has announced a new effort to study the use of computer games as teaching tools for mathematics and science. (eSchool News, November/December 2008). A spokesperson for Microsoft recently spoke to the organization's mission, saying "Technology has the potential to help reinvent the education process and excite and inspire young learners to embrace science, math and technology" (eSchool News, November/December 2008). The Games for Learning Institute (G4LI) is investigating which qualities of computer games engage students in an effort to develop relevant teaching strategies (eSchool News, November/December 2008).

As GIS become more and more mainstream, it is interesting to ponder what future scientists and practitioners will point to as the greatest contribution of GIS to our society. While the subjects of data visualization, geoprocessing capabilities and superior cartographic products are important, another notable contribution on this list will probably be the heightened role of spatial thinking (Dobson, 2004).

At the present, ArcGIS remains largely an expert based, "industrial strength" technology, a powerful and intriguing tool that is at once challenging and inviting, but also intimidating with a steep learning curve (National Research Council, 2006). A small but growing number of educators and school systems are investing the time and budget to installing computer labs and workstations capable of running ArcGIS. There are other alternatives to implementing a full scale ArcGIS setup, software platforms and tools that emphasize the use of geospatial technologies and promote or refine spatial thinking skills, ArcExplorer Java Edition for Education (AEJEE), ArcExplorer, Google Earth, My Wonderful World and GeoMapApp are some of the more well known. According to National Research Council (2006), spatial thinking in the K-12 curriculum can be supported and facilitated by choosing a tool that can (1) address a range of inquiry based problems; (2) use a variety of types and amounts of data; and (3) require different levels of skills and experience. In order to qualify as a support system for spatial thinking, three basic requirements must be met by the suite of tools: (1) capability to spatialize data; (2) facilitate visualization of the process and final results; and (3) perform a range of functions to include, but not exclusive of transformations, operations and analyses (National Research Council, 2006).

Conclusion

For the purposes of the case study with Corvallis High School which is the focus of this paper, GeoMapApp was chosen as the software platform to bypass many of the challenges of implementing a full suite of ArcGIS capable computer stations in a public high school. The GeoMapApp application met the criteria of many of the aims of integrating spatial thinking into a high school setting, including the ability to address a range of inquiry based problems, use a variety of data types and function well among a range of different technological proficiency levels. Even the most novice computer users, those who self reported a low interest and experience level with computer mapping were able to learn the tools and capabilities of the program within the three classroom sessions to a level sufficient to complete the open ended scenario activity. The participants were able to learn with a GIS, the GeoMapApp program, rather than spend all the class time learning about the GIS (functionality and capabilities).

This study addressed four primary questions:

1) What advantages are there to using an interactive, immersive geovisualization in the design and implementation of curriculum at the high school level?

As evidenced by the quantitative analysis and changes in scores, the main advantages to using an interactive, immersive geovisualization in the classroom include a development deeper levels of understanding and higher levels of comprehension of the mapping and oceanographic concepts introduced. The level of engagement, as observed during the classroom sessions was high and the interest level of the students, both observed and self reported, showed promising results related to the use of geovisualizations. Based on this study, I would recommend that all high school teachers with access to adequate technologies consider using computer mapping software in their curriculum. By presenting science material in a user friendly format, namely computer platforms, students show a high degree of involvement, engagement and participation in the educational process.

2) How can multimedia digital technologies best be utilized in aiding students to achieve the educational standards related to geography, science and technology?

Based on the observations and results of this study, it is apparent that multimedia digital technologies can be used to stimulate interest in science and encourage classroom participation. These tools can also be used in a multidisciplinary fashion, and the combination of skill development and higher level thinking, such as the open ended scenarios the Corvallis High School students completed on the third day of computer activities, extend beyond basic fact gathering and memorization, and in fact touch upon the upper hierarchy of Bloom's Taxonomy, to evaluation. The student's demonstrated knowledge acquisition was complemented with synthesis of facts and skills and included the ability to make judgments, in the case of deciding the ideal geographic location for a Marine Sanctuary. The best use of these multimedia digital technologies is in a multidisciplinary fashion. If educators can combine subject and content areas, they can meet multiple curricular goals within the constructs of the modern school systems, inherent with time pressures and a focus on standards based assessments.

The use of GeoMapApp as an educational tool shows promise for the integration of real world data sets and scientific tools in educational settings. The gap between how are students are prepared for careers and the tools used in that preparation can be narrowed by using tools that are derivations or subsets of the actual instruments and software packages that scientists use in advanced study. GeoMapApp is a data exploration tool that was originally designed to meet the needs of the oceanographic marine geology and geophysics research community, and has recently been adapted for use as a tool in K-12 education. By combining the technological capabilities with the tools available in a high school setting, educators can create dynamic, enriching and highly enjoyable educational activities that meet standards based requirements and improve numerous skills sets and pedagogical abilities. This evolution in applying real scientific tools represents a trend towards making the educational process as close to the real world science as possible. Improved technology has given our society access to digital multimedia and computing powers that allow public school systems to access and utilize powerful tools that were once exclusive to well funded scientific institutions. And the results described in this study indicate that students are eager to use these technologies, quick to learn complex skill sets, and capable of higher end learning in the classroom as a result of using them.

3) What pedagogical issues in secondary school curriculum development can be addressed with the use of interactive, immersive geovisualizations?

This study is promising in the consideration of how new technologies can help secondary school teachers meet the current demands on their performance and the overall goals of preparing students not only for assessments while in school, but for the high technology market place that awaits them. The key to encouraging widespread implementation seems to be mainly one of convincing administration, acquiring the necessary infrastructure and training educators to use the tools. The students themselves are the quickest to adopt the new and cutting edge tools, and are eager for curriculum that stimulates new modes of thinking and rewards digital learners.

4) How does the use of real world scientific data sets enhance educational practices?

The performance on the pre and post assessments indicates that using real world scientific data produces positive changes in the acquisition and utilization of geographic information and spatial thinking. The students self reported interests were high and indicated that using multimedia technologies and scientific data sets of a visual nature are excellent techniques for piquing interest and encouraging participation. Exploring data sets and presenting real world challenges, such as requiring the students to create a map layout of proposed marine reserves makes the task more credible, and gives the student's a sense of purpose in following through on a classroom task. As a result of this case study, Corvallis High School is expanding its use of geospatial technologies in several courses. At present, the lab consists of three workstations with ArcGIS software and twenty work stations with GeoMapApp. The interest and enthusiasm from students and staff is very encouraging, and validates the efforts of this study, while seeming to indicate a future growth of using geospatial tools and technologies.

Hopefully, this study can represent a growing trend toward moving away from memorization and teaching towards a select type of learner. Our culture and the digital age seem to favor the development and application of spatial thinking skills, and GIS is becoming mainstream. Perhaps it is time for our educational systems to discard worn out methodologies and embrace new technologies for our students.

The National Research Council (2006), committee recommended systems for supporting the use of spatial thinking developmental tools such as ArcGIS in schools, given the pragmatic challenges facing educators within these systems. Many educators are in agreement, and concur that a far superior and practical approach to teaching place based geography, and one that is gaining popularity amongst modern geographic educators is to teach to the habit of mind, a noted quality of a spatial thinker (National Research Council, 2006).

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Appendix 1. GeoMapApp Functions and Features

GeoMapApp is a freely downloadable Java™ application, and permits users to explore bathymetry data sets from the world's oceans, generate and download custom grids and maps, and explore a variety of other data types. The base bathymetry layers include data from the Antarctic Multibeam Synthesis and the Ridge Multibeam Bathymetry Synthesis and can be viewed at resolutions as high as 50 meters in some areas. The bathymetry layers are composed of grid and image tiles, at a variety of grid node spacings that are accessed via the internet by GeoMapApp. The GeoMapApp application is downloaded to a user's machine, compatible with a wide range of modern operating systems (MacOS 10.4 and above, Windows 98, 2000, XP, Vista, Solaris 2.7 and above, and GNU/Linux 2.4 and up). The application is run with an active internet connection that generates visualization of images as requested by the user, and the executable file, GeoMapApp.exe only requires 1 MB of free disk space and 64 MB of Random Access Memory (RAM) minimum, while 128 MB RAM is actually recommended for optimal performance. The development of GeoMapApp has been supported by Lamont-Doherty Earth Observatory and the National Science Foundation.

GeoMapApp is a diverse and multifunctional mapping tool, and includes basic navigational capabilities such as selection of location, pan, zoom in, zoom out, and scroll functions (Figure A1.1).

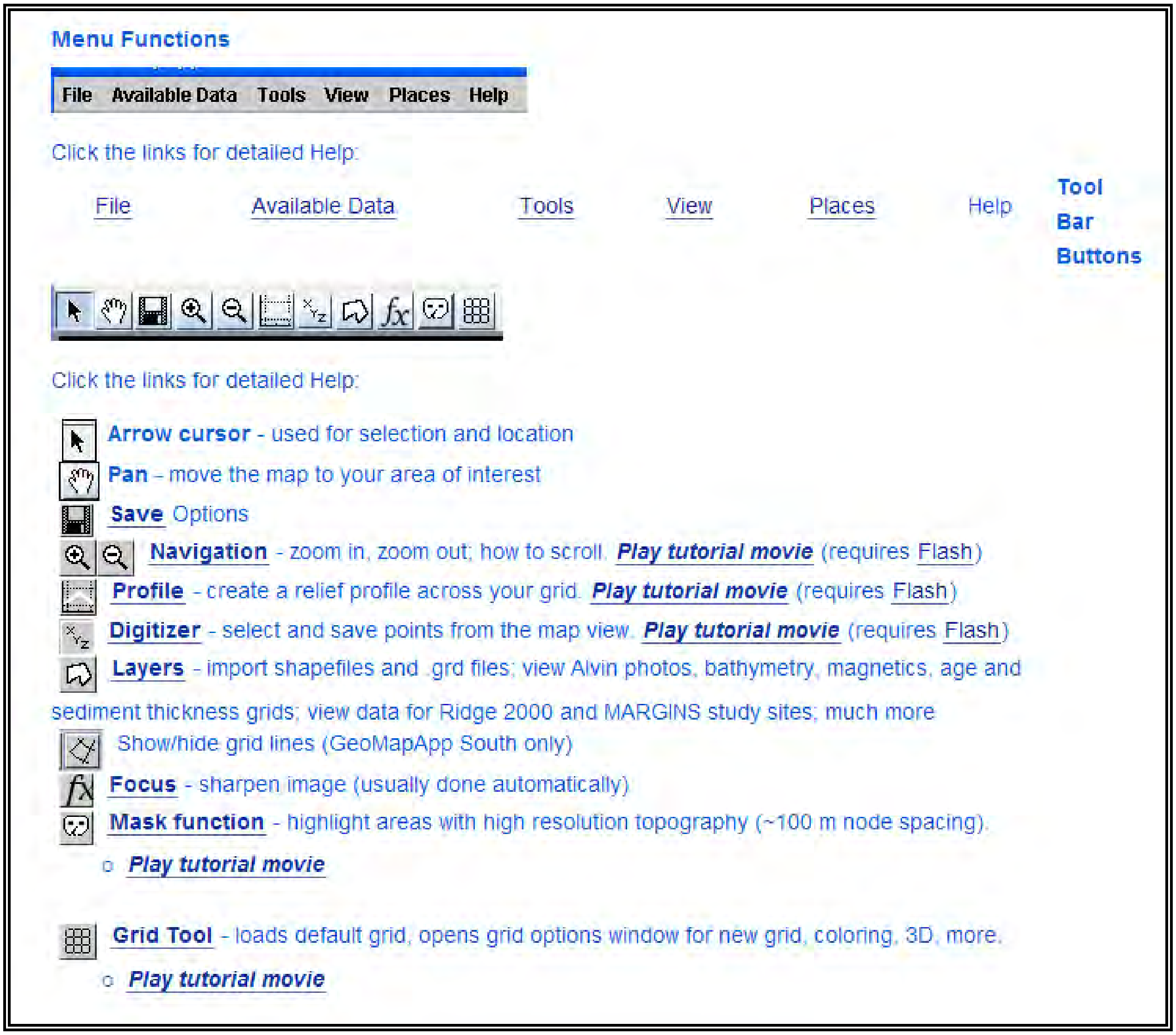


Figure A1.1. Screen shot of Menu Functions and Tool Buttons of GeoMapApp.

The software also includes a suite of tools that encourage spatial thinking and development of geospatial proficiencies. The Distance Profile tool creates a relief profile across the grid, and includes the functionality to display a location within the profile and on the map simultaneously (Figure A1.2). The Layers function allows the user to import ArcView shapefiles, ASC II and Excel formatted database tables, grid files, photos, bathymetry, magnetic, age and sediment thickness grids, Ridge 2000 and MARGINS study sites data. Data can be imported and manipulated with basic cartographic functions, such as color and appearance of lines and point data (Figure A1.3).

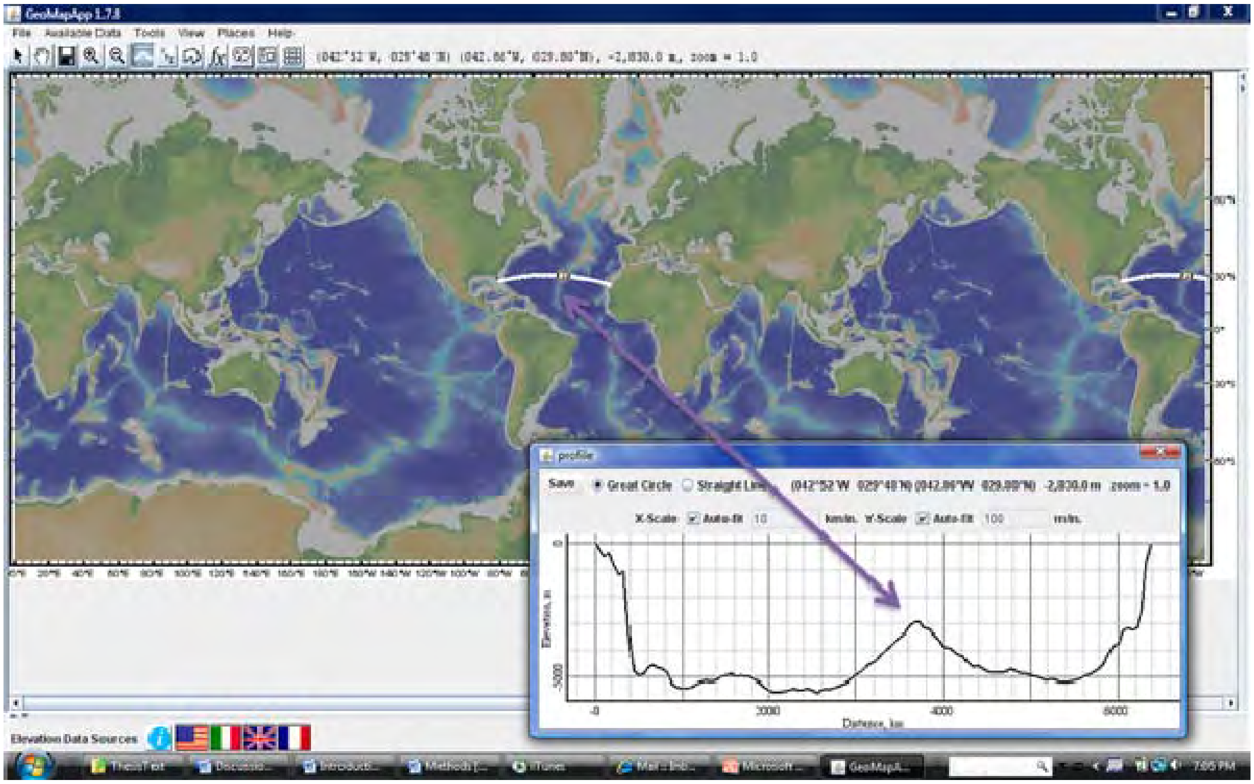


Figure A1.2. GeoMapApp screenshot showing Distance Profile Tool results of a transect across the Atlantic Ocean. The arrow is highlighting the function that shows the corresponding location of graph profile and map image, in this case a section of the Mid Atlantic Ridge.

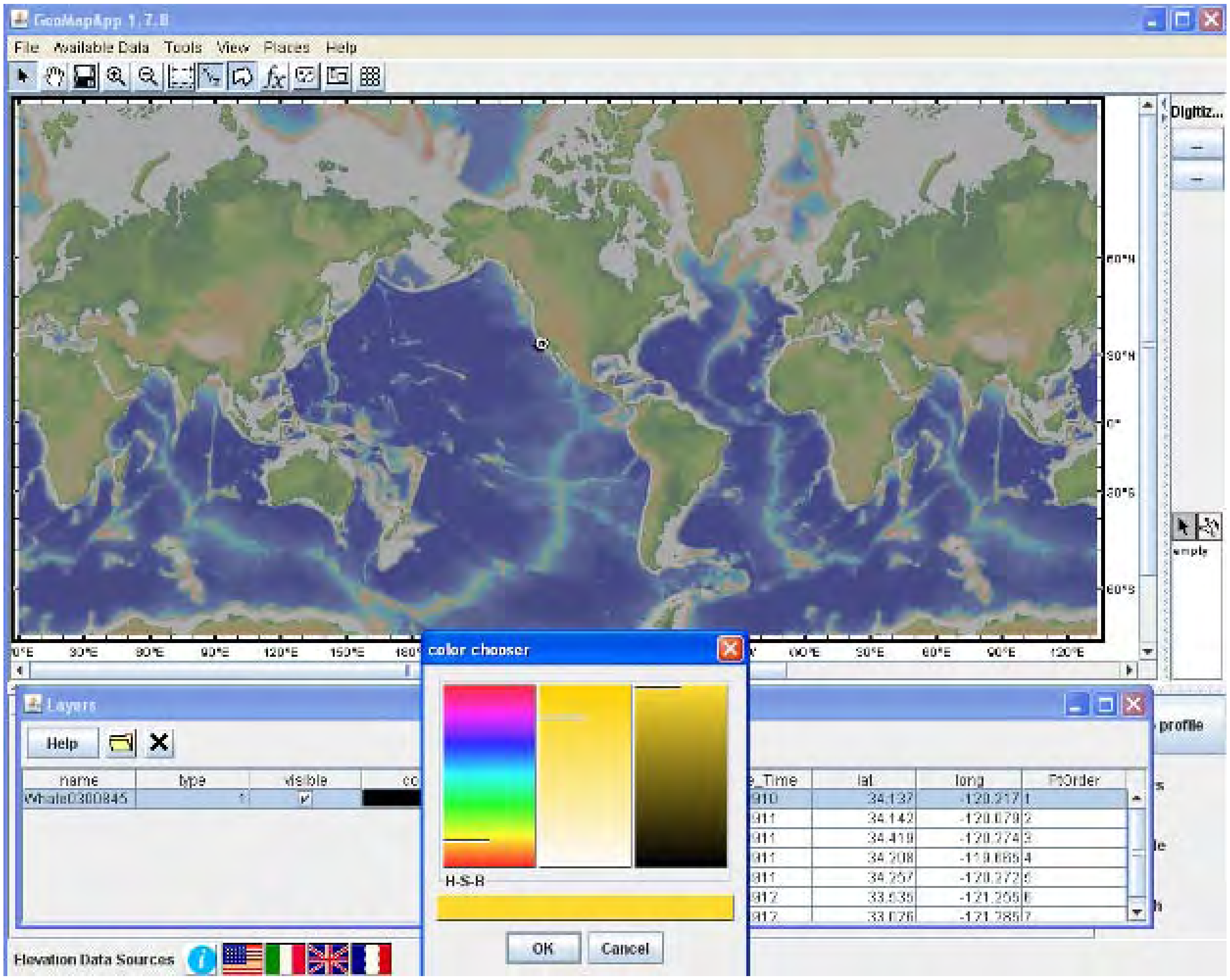


Figure A1.3. Screenshot of GeoMapApp project displaying imported data collected from satellite tagged blue whales in the Pacific Ocean near California, and the options for modifying the appearance of the data points overlain on the bathymetry layers. Blue whale data collected by the Marine Mammal Institute, Oregon State University.

The Digitizer tool selects and saves points from the map view, and can display the user created track lines as a table of point data, or a profile as shown in Figure A1.4. The yellow circles represent satellite fixes as recorded by the ARGOS Satellite monitoring system, the white line was created with the digitizer tool, and the profile chart represents the path taken by the whale and the depths of seafloor over which the satellite telemetry data was taken.

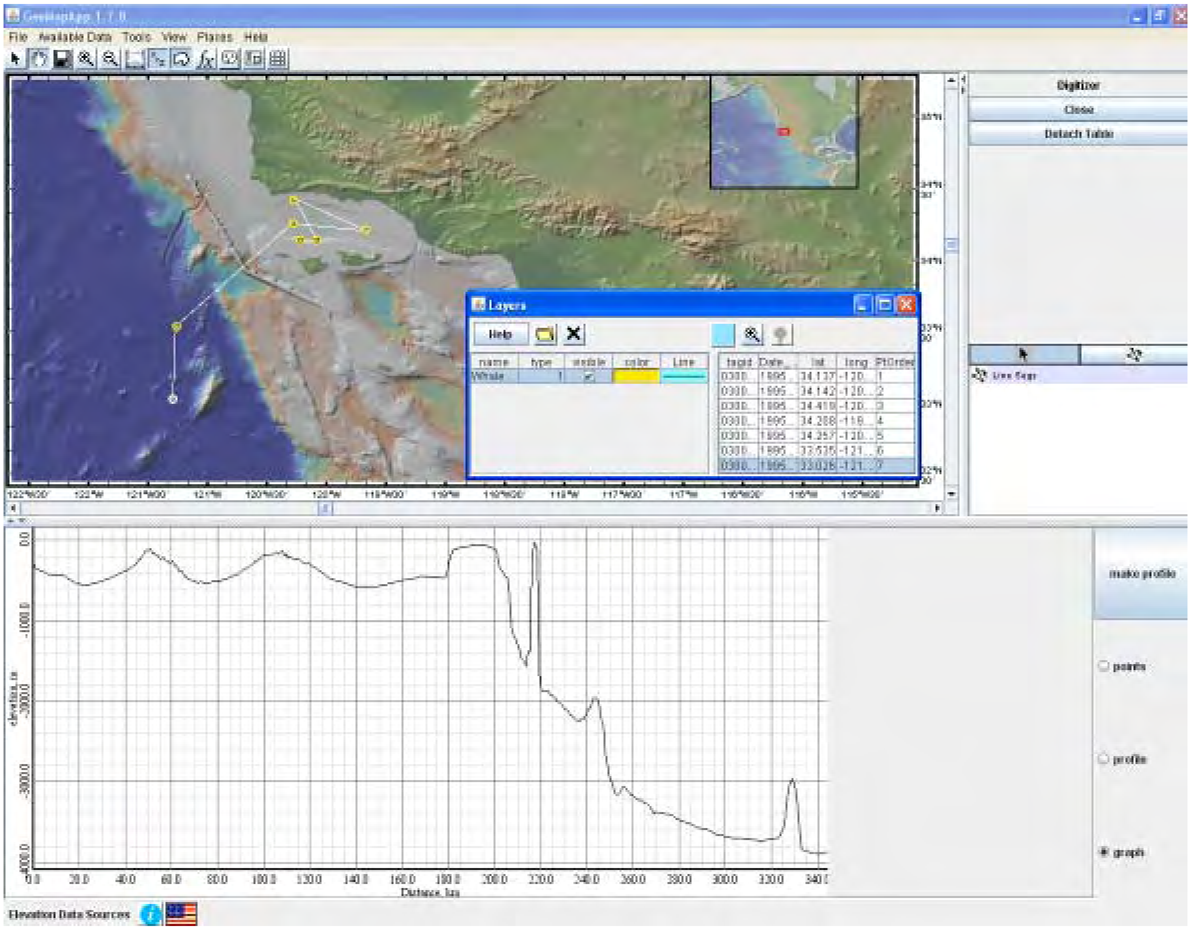


Figure A1.4. Screenshot displaying the functionality of the GeoMapApp DigitzerTool. This view displays a user created trackline across an imported data table of whale locations as collected from remotely deployed satellite tags on blue whales near the Channel Islands, off the coast of California. Whale data provided by Marine Mammal Institute, Oregon State Univeristy.

The Grid Tool loads the default grid, and opens the grid options window for new grid, coloring, 3D view and more (Figure A1.5)

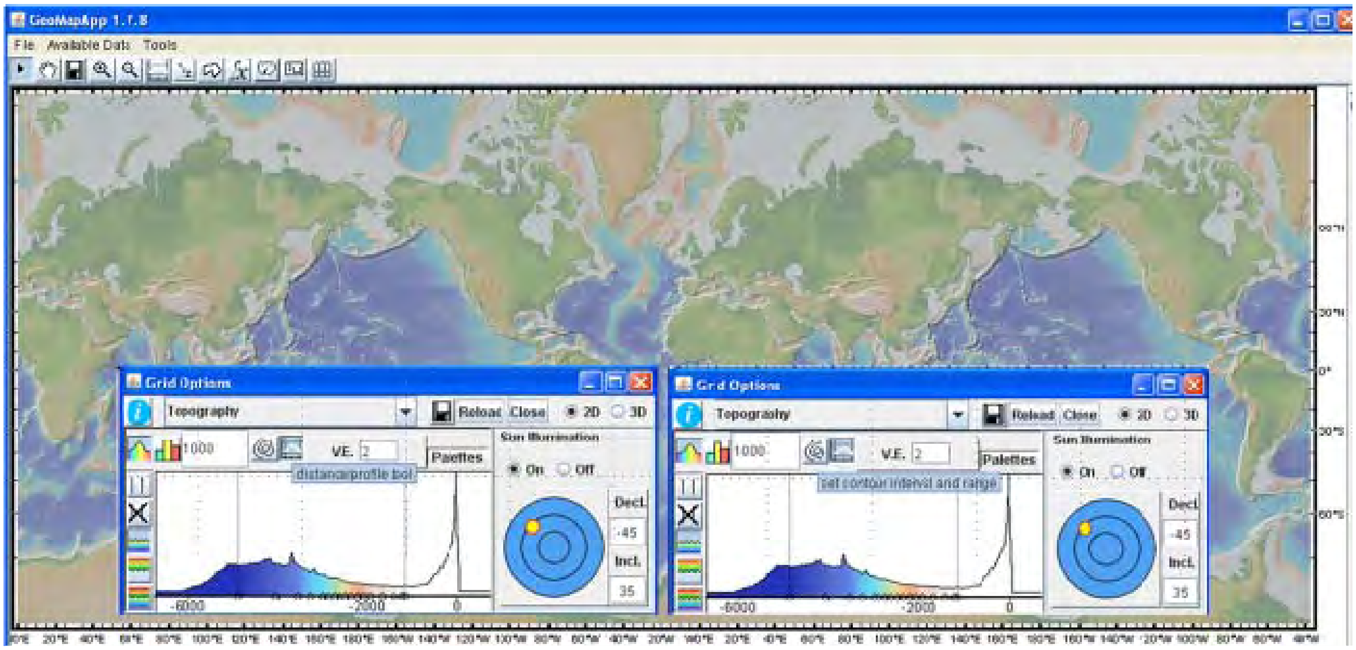


Figure A1.5. GeoMapApp session highlighting the grid functions allowing user to set contour interval and range, as well as change sun illumination, switch from 2D to 3D and use distance profile tool.

ArcGIS is an integrated collection of GIS software products, and provides an industry standard based platform for spatial analysis, data management and mapping. ArcGIS is founded upon key interoperability and Web computing concepts. Environmental System Research Institute, ESRI, is the commercial producer of ArcGIS, aligns to the specifications and standards of the Open Geospatial Consortium, Inc. (OGC), as well as those related to ISO, W3C, ANSI, and CEN. ArcGIS, in comparison to GeoMapApp, represents a more advanced, industrial strength technological platform. The minimum system requirements for the most basic of ArcGIS product call for 1 GB of RAM, a 1.6 GHz Processor and a PC-Intel platform running Windows Vista, Windows 2000 or Windows XP. The capabilities of this software are much more extensive and robust than GeoMapApp, and include mapping, advanced cartography, data support and interoperability, data editing, raster editing and vectorization, geoprocessing, modeling. In addition, there are hundreds of extensions and tools that work in conjunction with ArcGIS software to enhance the geospatial needs of numerous sectors of industry and academia. ArcGIS, in comparison to GeoMapApp, represents a more advanced, industrial strength technological platform.

Appendix 2. Geographic Literacy and National Geographic Standards

Geographic literacy is essential for living and functioning in a world that is rapidly changing due to technology and the digital tools of our era (Geography Education Standards Project, 1994). The world is becoming increasingly interconnected, globally, economically and culturally. Making decisions about where to live, where to work, and where to spend leisure time are all reliant upon knowing world geography. A 'Geographically Informed Person' sees meaning in the arrangement of things in space; sees relations between people, place and environments; uses geographic skills; and applies spatial and ecological perspectives to life situations. (Geography Education Standards Project, 1994). Being geographically illiterate makes a citizen, and potentially a community or nation isolated from the world. We now know that our own backyards are reliant upon the communities and cultures in countries across the globe. Our world is interconnected, integrated and interdependent. It is time for our curriculum across the grade levels to follow suit.

To be successful in today's global cultures and economies, students must develop a strong sense of the world and its places, in spatial terms, what National Geographic defines as 'geographic literacy'. The elements that make a geographically informed person, or one who is 'literate', are clearly outlined in the textbook *Geography for Life*, grouped into six Essential Elements encompassing Eighteen Standards, all benchmarked according to specific grade levels (Geography for Life, 1994). These recommendations for a geographically literate citizen are characterized according to competencies to be demonstrated at milestone grade levels, grouped as K-4, 5-8 and 9-12. These standards are further defined by detailed listings of what students should know and understand about a specific set of ideas and approaches, as well as skill sets describing what students should be able to do on the basis of this knowledge upon reaching Grades 4, 8 and 12 (National Geographic, 1994). Each standard is further distinguished according to 5 skill sets;

1. Asking geographic questions
2. Acquiring geographic information

3. Organizing geographic information
4. Analyzing geographic information
5. Answering geographic questions

The principles that underlie the five skill sets have been adapted from the *Guidelines for Geographic Education: Elementary and Secondary Schools*, prepared by the Joint Committee on Geographic Education and published in 1984 by the Association of American Geographers and the National Council for Geographic Education.
(Bishop and John F. Shroder, 1995).

With a few exceptions, the different types of visualization tools, static geovisualzations, dynamic geovisualizations, mapping software and serious games can all be used to address each of the eighteen geography standards grouped according to the six essential elements. Each tool type is appropriate within educational curricula in the development of a geographically informed person;

1) who sees meaning in the arrangement of things in space;
2) who sees relations between people, place and environments;
3) who uses geographic skills; and
4) who applies spatial and ecological perspectives to life situations.

(Geography for Life, 1994).

Educational tools such as GeoMapApp, ArcExplorer – Java Edition for Education (AEJEE) and ArcGIS can provide access to research quality data sets for use in inquiry-based activities. Despite our capabilities and advances, many questions remain about how to use these new geospatial tools and apply representational techniques to problem solving and knowledge construction**.** Table A2.1 suggests how the various types of multimedia tools can be used in curricula to address knowledge construction, as well as the other stages of learning described by Bloom's Taxonomy (Bloom, 1956).

Table A2.1. Using Multimedia Tools in curricula and pedagogical applications according to Bloom's taxonomy stages. (GMA† represents GeoMapApp, and other GIS‡ geographic information systems mapping software platforms such as ArcGIS, AEJEE, Google Earth).

		Multimedia Tool			
Bloom's Taxonomy	**Learning Skill**	**Geovisualization Static**	**Geovisualization Dynamic**	**Mapping Software (GMA†, GIS‡)**	**Serious Game (Interactive animations)**
Knowledge	memorization and recall	*	*	*	*
Comprehension	understanding	*	*	*	*
Application	Using Knowledge	*	*	*	*
Analysis	taking apart information		*	*	*
Synthesis	Reorganizing information		*	*	*
Evaluation	Making judgments			*	*

Table A2.2 illustrates the eighteen National Geographic Standards, grouped under the six essential elements and presents the author's suggestions on how various geovisualization tools can best be used toward achieving those goals. This table is adapted from the National Geographic publication, *Geography for Life*, and the author's experience using geovisualizations in educational settings. This table highlights the various strengths and uses of the four types of geovisualizations considered in this paper.

Table A2.2. Using multimedia digital technologies and geovisualizations in education
Evaluation of multimedia tool use in Geography education relative to National Geography Standards. (The * symbol used in Table A2.2 indicates that the geovisualization tool is appropriate for addressing the standard as a learning outcome or objective. The letter A indicates the tool is suited for assessment or measuring learning or standard competency, and the letter S indicates the tools is useful in skill development or standard acquisition).

Standard *The geographically informed person knows and understands:*	**Geovisualization Static**	**Geovisualization Dynamic**	**Mapping Software**	**Serious Game**
I. The World in Spatial Terms				
1. How to use maps and tools to acquire, process and report information from a spatial	*	*	*	*

perspective	A,S	S	A,S	A,S
2. How to use mental maps to organize information about people, places, and environments in a spatial context	❋ A		❋ S	❋ S
3. How to analyze the spatial organization of people, places, and environments on Earth's surfaces	❋ A,S	❋ S	❋ A,S	❋
Standard ***The geographically informed person knows and understands:***	**Geovisualization Static**	**Geovisualization Dynamic**	**Mapping Software**	**Serious Game**
II. Places and Regions				
4. The physical and human characteristics of places	❋ A,S	❋ S	❋ A,S	❋ S
5. That people create regions to interpret Earth's complexity	❋ A,S	❋ S	❋ A,S	❋ S
6. How culture and experience influence people's perceptions of places and regions	❋ A,S			
III. Physical Systems				
7. The physical processes that shape the patterns of Earth's surface	❋ A,S	❋ S	❋ A,S	❋ S
8. The characteristics and spatial distribution of ecosystems on Earth's surface	❋ A,S	❋ S	❋ A,S	❋ S
IV. Human Systems				
9. The characteristics, distribution, and migration of human populations on Earth's surface	❋ A,S	❋ S	❋ A,S	❋ S
10. The characteristics, distribution and complexity of Earth's cultural mosaics	❋ A,S	❋ S	❋ A,S	❋ S
11. The patterns and networks of economic interdependence on Earth's surface	❋ A,S	❋ S	❋ A,S	❋ S
12. The processes, patterns, and functions of human settlement	❋ A,S	❋ S	❋ A,S	❋ S

Standard *The geographically informed person knows and understands:*	Geovisualization Static	Geovisualization Dynamic	Mapping Software	Serious Game
13. How the forces of cooperation and conflict among people influence the division and control of Earth's surface	❋ A,S	❋ S	❋ A,S	❋ S
V. Environment and Society				
14. How human actions modify the physical environment	❋ A,S	❋ S	❋ A,S	❋ S
15. How physical systems affect human systems	❋ A,S	❋ S	❋ A,S	❋ S
16. The changes that occur in the meaning, use, distribution, and importance of resources	❋ A,S	❋ S	❋ A,S	❋ S
VI. The Uses of Geography				
17. How to apply geography to interpret the past	❋ A,S	❋ S	❋ A,S	❋ S
18. How to apply geography to interpret the present and plan for the future	❋ A,S	❋ S	❋ A,S	❋ S

Appendix 3. Additional Literature of Interest

Our society has changed dramatically over the past few decades, and technology permeates every aspect of our daily culture. Computers have literally revolutionized every aspect of our lives, and we are moving from the industrial age to an informational age (Goldstein, 2008). The way we communicate and experience the world has been transformed through technological advances, yet our school systems are often lagging in keeping up with all new trends and computing capabilities. Professional simulations are used in many industries, city planning, military strategic planning, weather forecasting, ecological studies, and engineering (Prensky, 2007). Proficiency in computer simulations is required in these and other contemporary career fields, and numerous science simulations are accepted as common in the workplace (Prensky, 2007). In a report released in 2005 by the U.S. Department of Labor Employment and Training Administration entitled *High Growth Industry Profile*, GIS was identified as one of the three most important emerging and evolving fields, along with nanotechnology and biotechnology (Goldstein, 2008). Over a quarter of the highly trained NASA geospatial professionals are slated to retire in the next decade (Goldstein, 2008). Clearly, GIS has a prominent and permanent position in the workforce, and a high potential in career and higher-education opportunities, and should therefore be a priority for implementation in K-12 classrooms.

To be proficient in geospatial technologies, candidates entering the work force need to have fundamental geographic literacy as well as spatial literacy. In the linguistic consideration, literacy entails the ability to read, write and speak in a language (National Research Council, 2000). National Geographic has published *Geography for Life* which defines geographic literacy according to benchmarks appropriate at grades 4, 8 and 12. The National Research Council has published a report entitled *Learning to Think Spatially* and defines spatial literacy as follows:

> Spatial literacy involves the ability to draw upon the skills of spatial thinking. Spatial thinking has three core components; concepts of space, tools of representation and processes of reasoning (National Research

> Council, 2000). The concept of space is demonstrated when an individual calculates distance (miles traveled, cost of travel), also in the concept of coordinate systems (e.g., Cartesian versus polar coordinates) as well as the nature of spaces (e.g., two dimensions versus three). Tools of representation can be the relationships among views (e.g., plans versus elevations of buildings, orthogonal versus perspective maps), differences among projections (e.g., Mercator versus equal-area map projections) and the principles of graphic design (e.g., legibility, visual contrast, figure-ground, graphing and mapping). The processes of reasoning can be defined as different modes of thinking about shortest distance (e.g., straight line 'as the crow flies' versus traversing along a rectangular city grid), extrapolation and interpolation (e.g., predicting a trend into the future based on a graph, estimating the slope of a map of contour lines) and making decisions (e.g., driving route chosen based on a radio traffic report). (National Research Council, 2000).

A spatially literate individual can draw upon spatial knowledge, has a core repertoire of spatial ways of thinking and acting and has the capacity to use these spatial capabilities to solve problems in all aspects of their lives (National Research Council, 2000).

Furthermore, studying geography and earth science in the digital age now requires a sophisticated and complex integration of concepts that include spatial and temporal aspects (Harrower, et al., 2000). The use of digital technology, including static and dynamic geovisualizations, geographic information software packages, and serious games or animations can encourage the development of spatial thinking skills and promote the 'habit of mind' characteristic of a spatial thinker.

One topic gaining popularity in this era of digital revolution is the idea of integrating gaming platforms and educational settings. Many researchers and educators are looking towards the use of gaming in education, and a small but growing number of advocates are developing tools and simulations for use in meeting educational objectives. In a poll conducted by eSchoolNews in March of 2008, only 19 percent of parents and 15 percent of administrators agreed with the more than 50 percent of students that would like to see gaming integrating into school work (Stansbury, 2008). These students already spend 8 to 10 hours per week on average playing online or electronic games. This seems like a tremendous skill base with a high level of interest that educational systems could tap into.

How did the teachers rank in this survey? More than 50 percent of the teachers polled said they would be interested in learning more about integrating gaming technologies and spending time on professional development on this topic, yet only 11 percent indicated they are currently incorporating some aspect of gaming in their instruction (Stansbury, 2008). Yet educators face the challenge of finding and integrating computer games that are relevant to the established curriculum (Ash, 2008). Experts draw correlations between science and gaming, pointing to the commonalities of curiosity, inquiry and investigation – qualities which are fundamental to both scientists and avid gamers (Ash, 2008).

What can we do to begin educating our 21st Century children with 21st Century technology tools? We must address the barriers to adoption of technologies such as GIS and serious games in curricula; lack of money, lack of time, lack of knowledge or training, lack of resources such as learning modules, lack of technology and a common belief that serious games cannot address standards based curricula. The political factors influencing educational content and operation will continue to be pressing issues; funding, time and technological system support all need to be addressed. The pivotal issue that can turn the focus in current school systems toward implementing serious gaming is the standards based curriculum development. If we can design and offer simulations that meet educational objectives currently delegated to our nation's teachers, the other issues of funding, time and access to technology will surely follow suit. The key lies in rigorous assessment tools and capabilities built into the gaming environment, to assure busy educators that the time spent in animated environments can also be educational. Educators need empirical evidence for themselves as well as administrators in order to encourage the curricular reform that would precede a shift in the use of technology, including geovisualizations of all types.

The world wide web has made our global community come closer together, and has resulted in a climate and culture than encourages and rewards individuals who can assimilate facts and concepts from a multitude of disciplines into coherent and cognizant thought processes. Learning with Geographic Information Systems (GIS) rather than about them shows great potential in educational arenas (Hall-Wallace and McAuliffe, 2002). Field testing found positive correlations between spatial ability and performance on assessment testing, and demonstrated that GIS was useful for identifying geographic locations and features, interpreting topography and conceptualizing two and three dimensional representations (Hall-Wallace and McAuliffe, 2002).

Carlson (2007) recognizes that Geographic Information System education blends a focus on spatial concepts with theoretical foundations through the representation of spatial data. The capabilities of GIS as a tool; query, analysis, representation and assimilation of data, encourage thinking that spans many disciplines and schools of thought. The highly engaging visual nature of a GIS suite of tools, combined with the interactive powers of a geovisualization encourage creativity and success in students that might not excel in more traditional pencil and paper based tasks or measures of aptitude.

As illustrated by the brief math lesson in Figure A3.1, the fact memorizing approach to geography is futile and quickly reaches a point of staggering and overwhelming dimensions (Gersmehl and Gersmehl, 2007).

Facts About Places (and why you can't possibly learn them all)

	Total So Far
Stand in the middle of a room in your house.	
Write ten facts about the wall you see in front of you.	**10**
A typical room has 4 wall. Multiply by 4.	**40**
A typical house has 5 rooms. Multiply by 5.	**200**
Add facts about the outside and yard. Add 50.	**250**
A typical block has 20 houses. Multiply by 20.	**5,000**
A community might have 50 blocks. Multiply by 50.	**250,000**
The U.S. has approximately 40,000 communities. Multiply by 40,000.	**1,000,000,000**
The world has 20 times as many people as the U.S. Multiply by 20.	**20,000,000,000**
So far, we have considered only houses. Add facts about other features: oceans, lakes, rivers, mountains, deserts, islands, farm fields, barns, pastures fences, windmills, stores, factories, offices, churches, cemeteries, restaurants, theaters, parks, airports, etc.	**at least 500,000,000,000**

Conclusion: We study geography in order to learn some skills that can help us organize and remember important facts out of the mass of information.

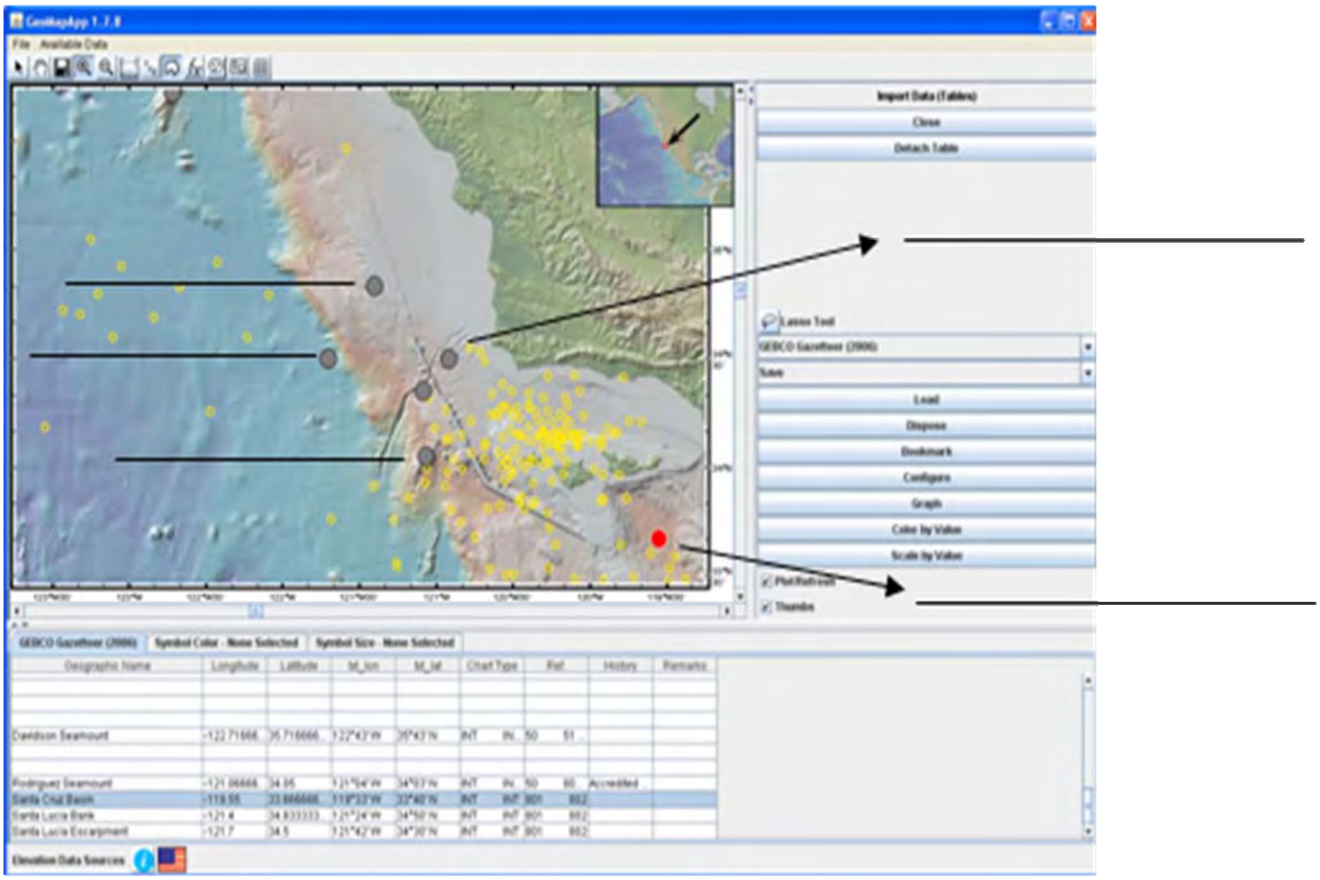
Figure A3.1. The Numerology of Place Based Geography. A brief math lesson to illustrate the futility of trying to learn facts about every place in the world. Adpated from Gersmehl and Gersmehl, 2007.

While geography courses can contain overwhelming or daunting lists of facts if they focus solely on place based geography, most educational efforts have a long tradition of relying on a multitude of pedagogical approaches. One approach to avoiding the encyclopedic method of studying geography is to focus on the five fundamental themes in geography: location, place, relationships within places, movement and regions (Nellis, 1994; Stanfield, 2008). These themes can be addressed using a GIS as a tool in geographic education. Previously, other scholars have recognized the appropriateness of implementing the use of geographic information systems in the teaching of geography. Mark and Dickerson (1991) noted the correlation of GIS use and Pattison's (1964) four traditions of geography – spatial analysis, regional characterization, demonstration of human-environment interaction and modeling of earth science processes.

GIS allows us to answer complex spatial questions, and in fact, can be considered a spatial decision support system that integrates data and related information about geographical locations of the world into a digital medium. This digital medium provides a catalyst for creative thought (White and Sims, 1993). In this sense, a GIS fosters spatial thinking and encourages the development of a 'habit of mind', as opposed to rote memorization of factual information. And in this informational age, the value of skill memorization is being replaced with the value of being skilled at accessing and interpreting information. With the proliferation of technology in mainstream and the workforce, today's students must be adept at accessing, processing, interpreting, and working with large amounts of data. By teaching with geovisualizations, we can foster skill with digital technologies, develop spatial thinking skill sets and use geographic based lessons to help students move towards mastery of geographic standards, and assist students to become masterful spatial thinkers. The emphasis should not be on the box or the buttons, but rather the use of the tools and technologies as catalysts for deeper learning and higher comprehension in alignment with pedagogical agendas within educational arenas.

Appendix 4. GeoMapApp Worksheet #1

GeoMapApp© Worksheet 1- Basic Skill Review



1. Add the Blue Whale Data

Choose File from the menu → Import Data Tables → Import from Excel formatted (.xls) file → Choose file named **blue95CA.xls**
Click Open → Click OK → Click 'Color All' → Choose a color

2. Add the geographic names

Choose 'Available Data' from the menu → Select Data From Menu → General Data Viewers → Tables →
Geographic Names → GEBCO Gazeteer (2006)

3. Click on the gray icons and fill in the names of the seafloor features in the spaces provided above

Appendix 5. GeoMapApp Worksheet #2

GeoMapApp Worksheet #2
Name
Block

Sketch an x, y profile of a seamount chain

Sketch an x, y profile of a trench

Sketch an x, y profile of a ridge

Describe the location of the seamount chain

Describe the location of the trench

Describe the location of the ridge

Fill in this data table

Whale Species	**Latitude**	**Longitude**	**Depth**
Blue Whale			
Right Whale			
Bowhead Whale			

What is the average depth for a Blue Whale?

What is the average depth for a Right Whale?

What is the average depth for a Bowhead Whale?

Describe the patterns you see in the data for each species:

Blue Whale

Right Whale

Bowhead Whale

Appendix 6. Open Ended Scenario

Scenario: You are a marine mammal biologist working for the National Marine Fisheries Service. You have been asked to prepare a report about the migrations and movements of blue whales along the Pacific Coast of North America. You must give information about the locations of the whales and the seamounts they might be feeding on.

As part of your report, please propose an area in Canada, United States and Mexico for a Marine Reserve. You can propose a marine reserve area no greater than 250,000 square km. Your reserves in Mexico and the United States should include at least one seamount.

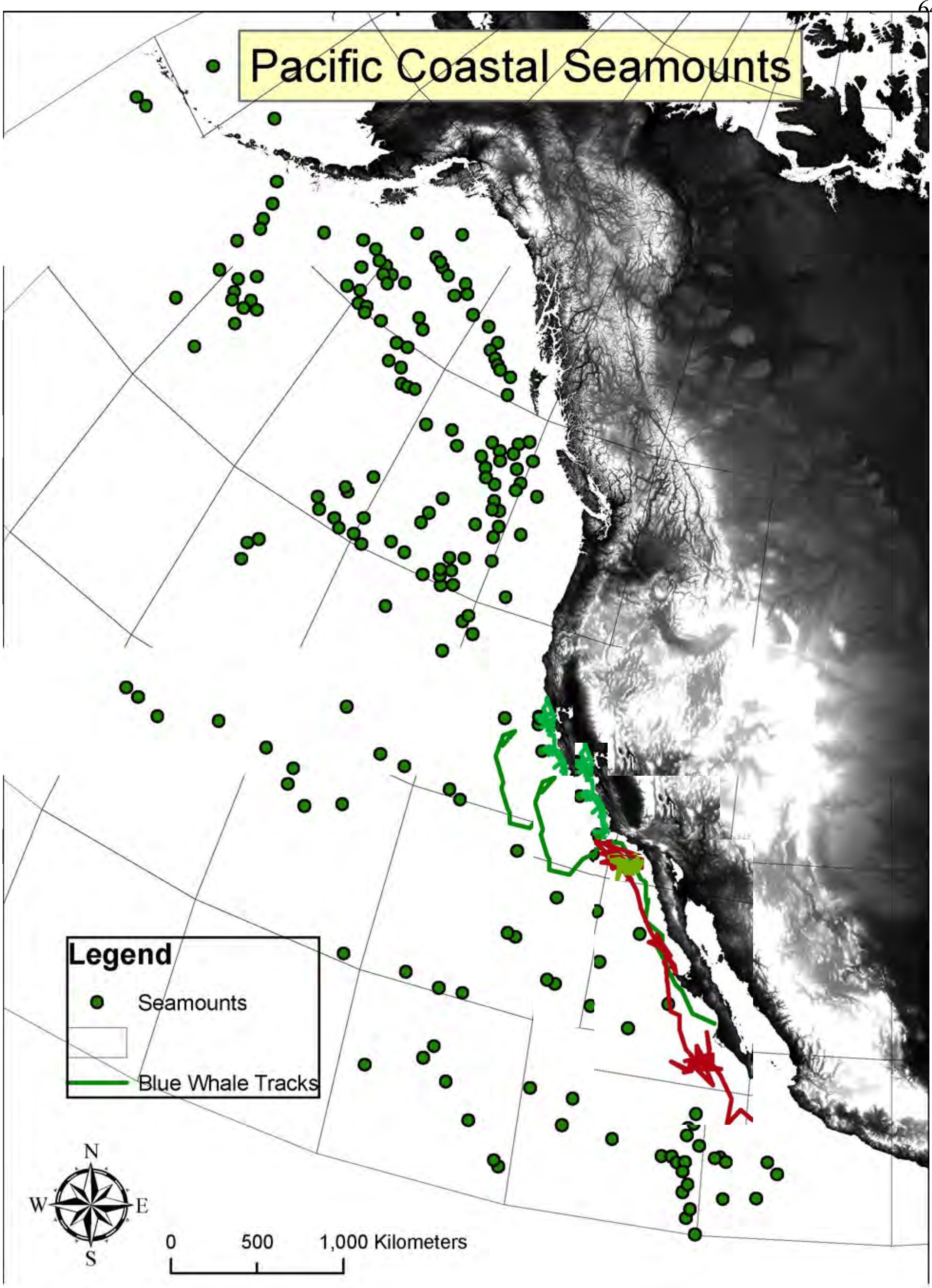
Once you have chosen your reserve, estimate and report the depth, distance from shore and slope of the seamounts inside the reserve. Draw your reserve on the map titled 'Pacific Coastal Seamounts'

NAME	DEPTH	LAT_DD	LONG
GUMDROP	-1207	37.45	-123.467
STEEL VENDOR	-1611	40.38	-129.45
RODROGUEZ	-651	34.05	-121.07
SAN JUAN	-546	33.03	-121
JASPER	-1089	30.42	-122.76
FERREL	-567	29.54	-117.29
WESTFALL	-1253	30.18	-120.08
CERRALVO	-305	24.18	-109.6
CABRILLIO	-1084	22.82	-109.28
DISPATCH	-1307	27.66	-119.36
HENDERSON	-1173	25.34	-119.56
FAIRWEATHER	-1907	19.85	-113.08
SUITCASE	-1963	20.66	-112.72
ROSA	-955	26.18	-115
CREST	-2020	24.54	-117.08
SM_01_1C	-921	18.42	-119.52
SM_02_2D	-969	26.02	-121.8
SM_01_2D	-1111	26.14	-122.28
TANEY	-2160	36.85	-125.617
GUIDE	-1700	37.03	-123.37
DAVIDSON	-1253	35.76	-122.7038
PIONEER	-813	37.37	-123.43

Table 1. Seamount Data for Pacific Coastal Regions of California and Baja California.

Longitude	Latitude	Depth of Seamount	Distance to shore	Slope of Seamount

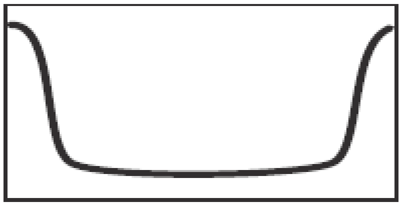
Table 2. Seamount Data for Proposed Reserves

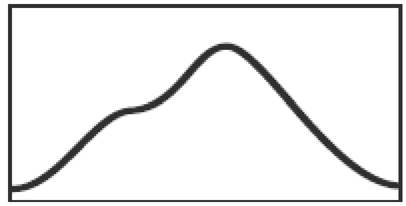


Map created using ArcGIS 9.2 software. Cartography by Michelle Kinzel.
GIS Data courtesy of Marine Conservation Biology Institute, www.mcbi.org.

Appendix 7. Testing Instrument with National Geographic Standards Correlations

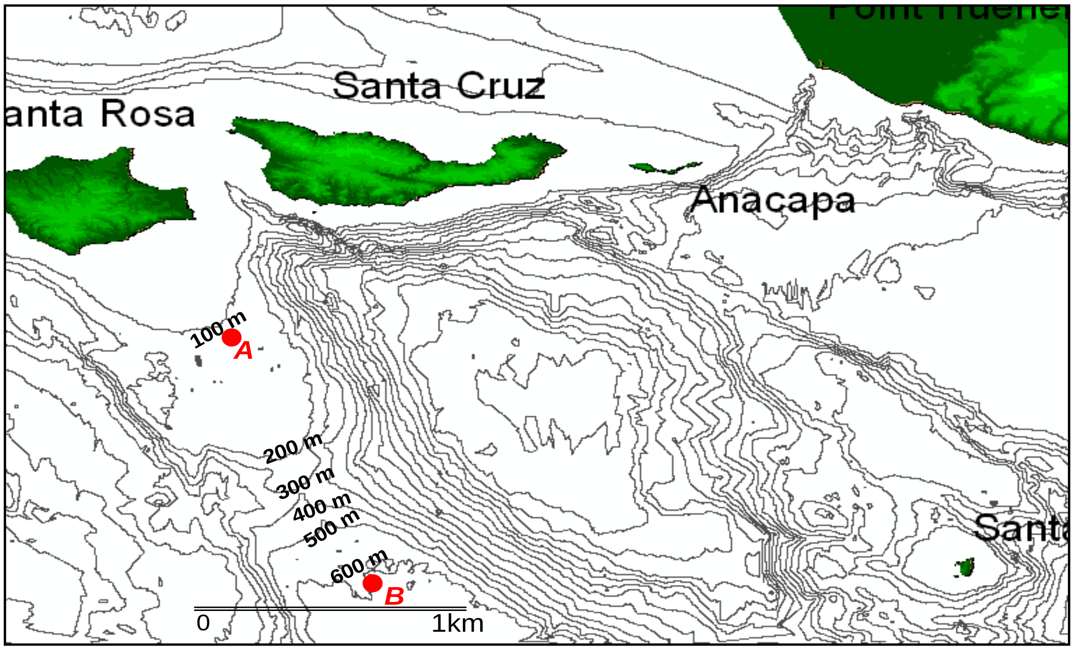
If this is a profile view of a bathtub, and this is a profile of a mountain range:





sketch what you *think* a profile of the seafloor looks like across the Atlantic Ocean along a ships path from East Coast of North America to West Coast of Africa.

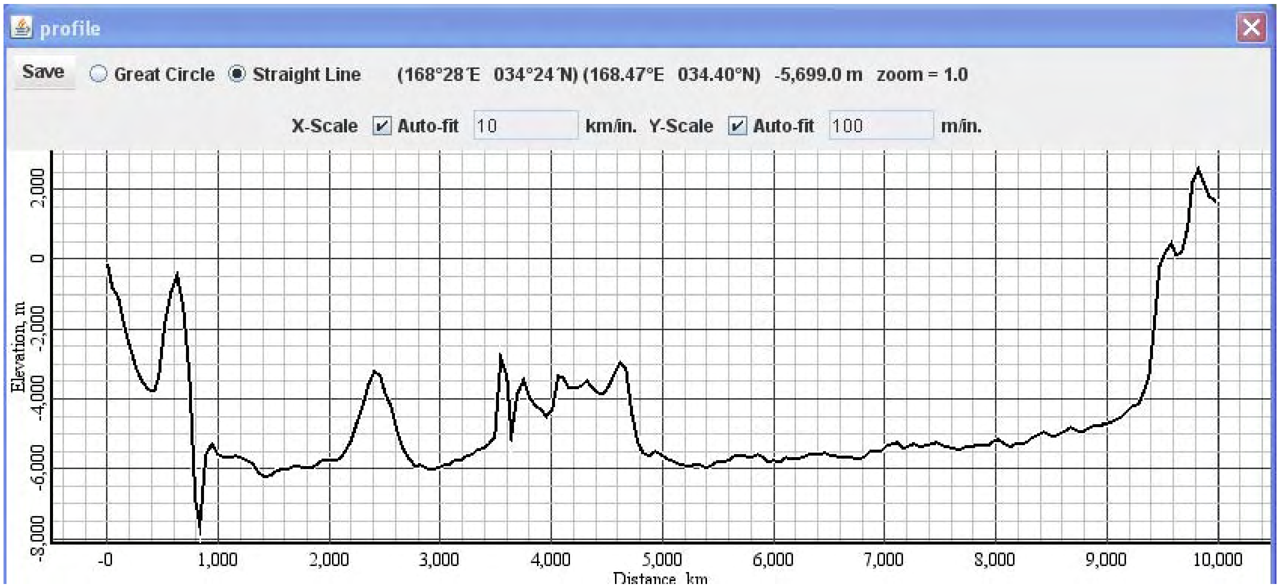
Question 1. Open ended question to assess student's understanding of seafloor topography.
National Geographic Standards 1, 2, 3, 4, 7



Using the diagram above, can you estimate the slope (change in depth/distance) between points A and B?

Question 2. Map Interpretation. Math Skills, estimate slope between 2 points. National Geographic Standards 1, 3, 7

Instructions: Please complete the following questions. For the open ended questions, write as much as you know or can think of for the answers.



What does the x axis represent?
What does the y axis represent?
Question 3 and 4. Graph Interpretation
National Geographic Standards 1, 3

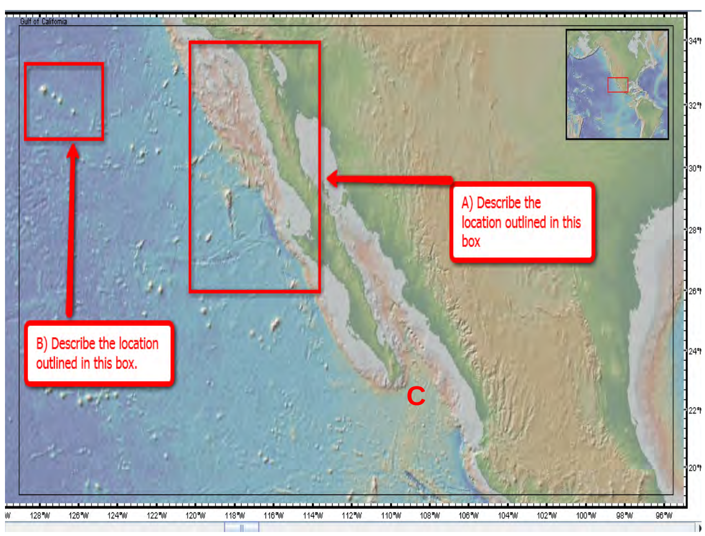
Between 600 and 800 km along this profile line, how much does the elevation change?
Question 5. Graph Interpretation.
National Geographic Standards 1, 3

How would you describe the slope(change in elevation/change in distance) between 600 and 800 km:
a) extremely steep
b) steep
c) flat
d) gently sloping
Question 6. Multiple Choice/Graph Interpretation.
National Geographic Standards 1, 3

What is the slope in this area (change in elevation/change in distance)?
Question 7. Graph Interpretation. Math Skills, estimate slope between 2 points.
National Geographic Standards 1, 3

What do you think this graph represents?
Question 8. Open ended question. Graph Interpretation.
National Geographic Standards 1, 3

Contour lines are:
A) used to indicate depth of the seafloor
B) indicate change in elevation on a mountain
C) found in a map of the bottom of the ocean
D) can be used to calculate slope over a known area
E) all of the above.
Question 9. Multiple Choice. Graph Interpretation.
National Geographic Standard 3



Use this image to answer parts A, B and C below.

A) Describe the location outlined in box A. List as many features and geographical descriptions as you can.

Question 10. Open ended. Map Interpretation.

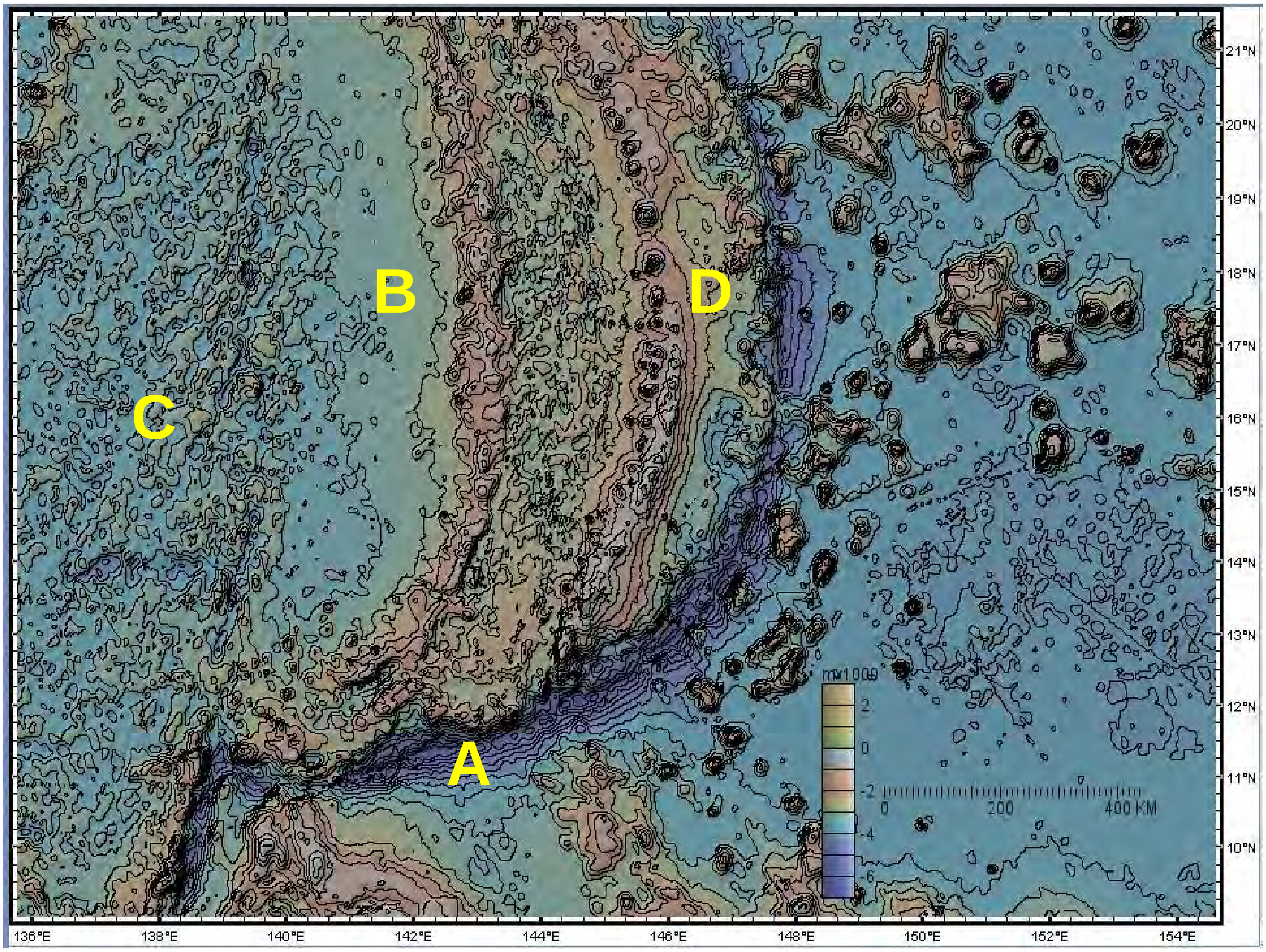
B) Describe the location outlined in box B. List as many features and geographical descriptions as you can.
Question 11. Open ended. Map Interpretation.

C) Describe the location represented by the letter C.

Question 12. Open ended. Map Interpretation.

Q 10, 11 and 12. Map Image, Screenshot from GeoMapApp, Land and Seafloor of Baja California and Pacific Ocean Region.
National Geographic Standards 1, 2, 3, 4, 8

The next 3 questions refer to this diagram, which shows an area of the seafloor that includes the Marianas Trench in the Pacific Ocean. Use a letter for A – D for each answer.



Where is the deepest part of the ocean in this diagram? ___________
Question 13. Matching. Map Interpreation.

Where is the slope the steepest? ______________________
Question 14. Matching. Map Interpreation.

Where is the slope the least steep (flattest part of sea floor)? ________________
Question 15. Matching. Map Interpreation.

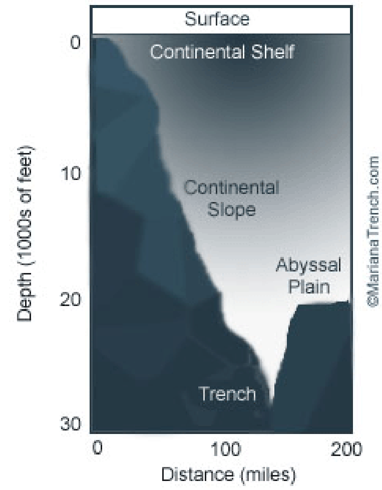
Q 13, 14, and 15. Map Image, Screenshot from GeoMapApp, Seafloor including Mariana's Trench in the Pacific Ocean.
National Geographic Standards 1, 3, 4

Match the following profiles with the ocean floor feature type they represent by writing the corresponding letter next to the name below:

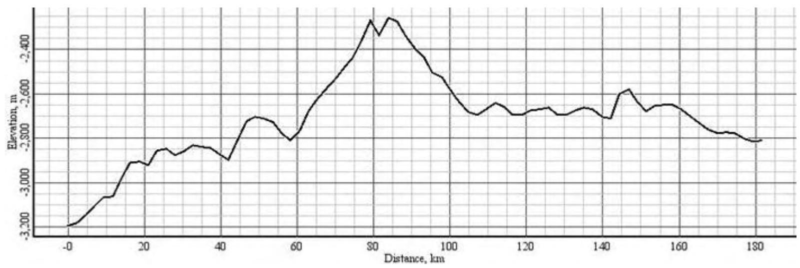
1. seamount chain ____________

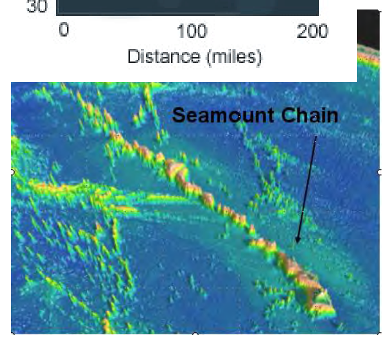
2. trench ________________

3. ridge _________________

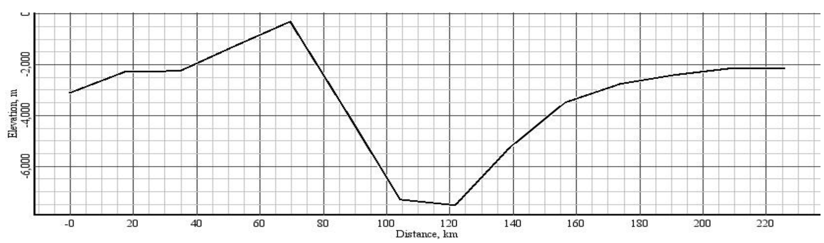


A

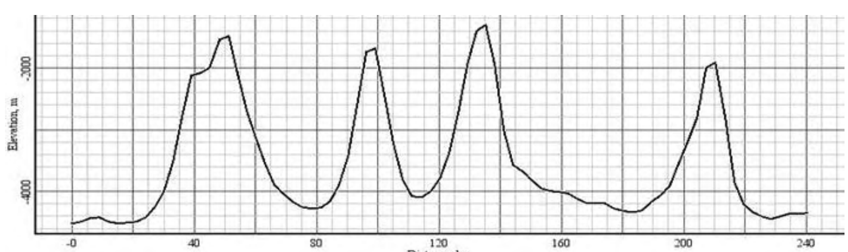


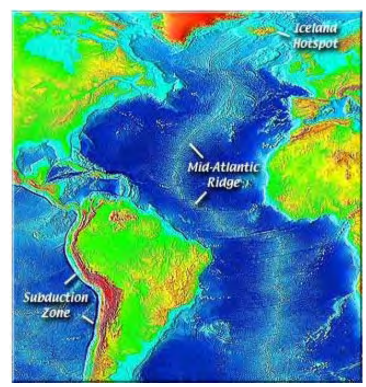


B



C



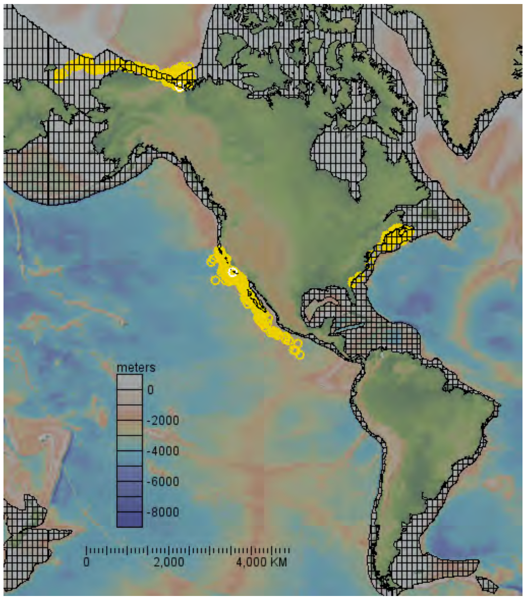


Question 16, 17 and 18. Matching 2 Dimensional GeoMapApp Graph Profile to 3 Dimensional Image.

National Geographic Standards 1, 2, 3, 4, 7, 8

This map shows the distribution of whales, marked with yellow circles, as identified with satellite data.

What patterns do you see in the data?



Question 19. Open ended, Map Interpretation. Map of North America, Pacific and Atlantic Oceans with representations of locations of satellite tagged whales (Bowhead Whales, Blue Whales and Right Whales).
National Geographic Standards 4,7,8

Which profile has the following characteristics associated with it.
You answer could include both, one or none of the profiles.

1. Represents a section of the seafloor and land above sea level: _____________

Question 20. GeoMap App Profile, Graph Interpretation.

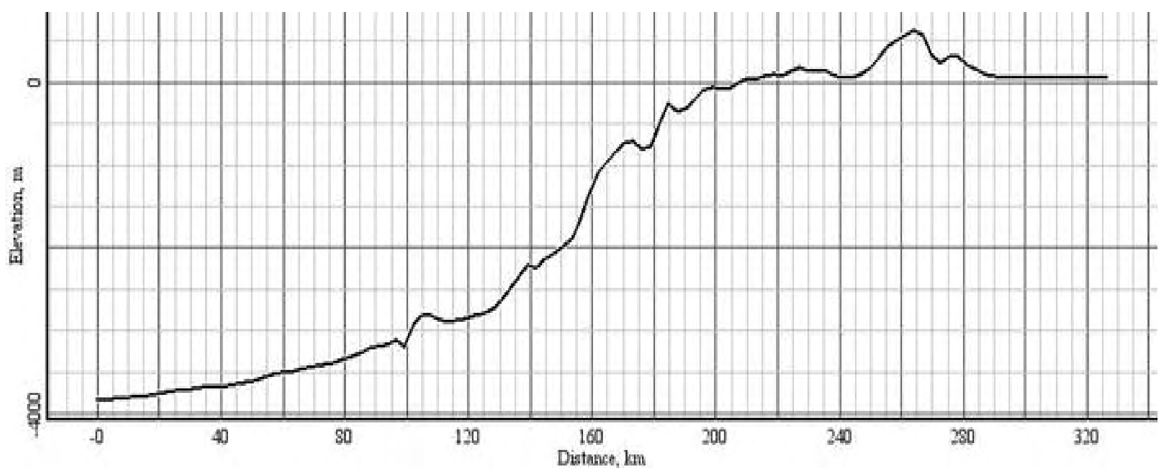
2. Could represent the seafloor beneath a ships path across the Atlantic Ocean ________

Question 21. GeoMap App Profile, Graph Interpretation.

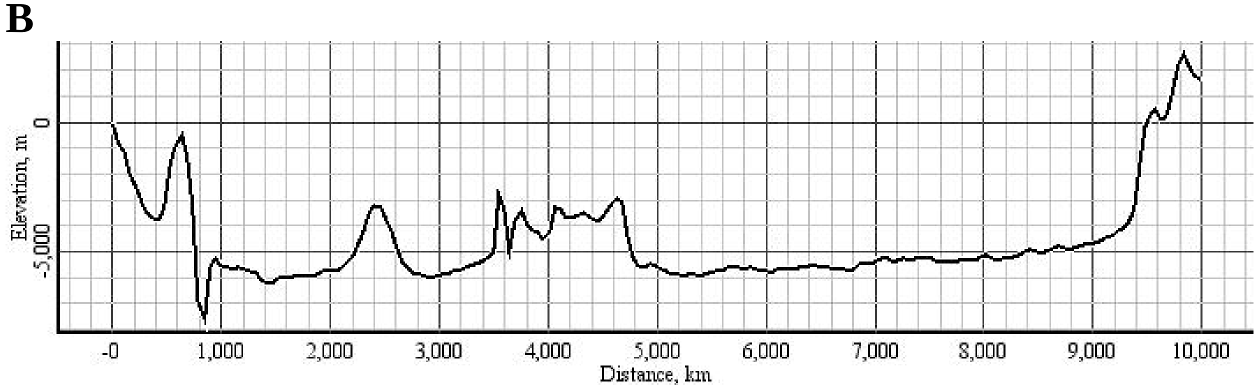
3. Crosses a very deep trench in the ocean ______________________
Question 22. GeoMap App Profile, Graph Interpretation.

4. Begins at a location far below sea level ___________________
Question 23. GeoMap App Profile, Graph Interpretation.

A



B



Question 20-23. National Geographic Standards 1, 2, 3, 4, 7, 8

Appendix 8. Student Self Reported Profiles, Pre-Test Survey and Post-Test Survey

Pre-test Student Survey

Code Number ______________________

Please answer these questions:

1. I have used a GPS unit
    a. Never
    b. 1-2 times
    c. 3-5 times
    d. More than 5 times

If you chose "d", approximately how many times have you used a GPS unit _________

2. I have used Google Earth
    a. Never
    b. 1-2 times
    c. 3-5 times
    d. More than 5 times

If you chose "d", approximately how many times have you used Google Earth _________

3. I have used other Computer Mapping Software (Yes/No)

If yes, the name of the software I have used

4. I play video games
    a. Never
    b. Once a week
    c. 2-6 times a week
    d. Every day

5. The number of hours per week I play video games is
    a. 1-2 hours
    b. 3-4 hours
    c. 5-6 hours
    d. 7-8 hours
    e. +8 hours per week

If you chose e, approximately how many hours per week do you play video games
____

6. What are your top 3 favorite video games?

7. If you use a computer at home or during your free time (outside of class) what activities are you most likely to do? (email, Google Earth, surf the internet, play video games, watch DVD's, others…)

Please rank your interest in the following activities
0 = I am not at all interested, and 10 = I am very interested

Playing Video Games
0 1 2 3 4 5 6 7 8 9 10

Using a cell phone to talk
0 1 2 3 4 5 6 7 8 9 10

Using a cell phone for text messaging
0 1 2 3 4 5 6 7 8 9 10

Playing Online Video Games with Others
0 1 2 3 4 5 6 7 8 9 10

Surfing the Internet
0 1 2 3 4 5 6 7 8 9 10

Using Google Earth
0 1 2 3 4 5 6 7 8 9 10

Using a GPS unit to Geocache
0 1 2 3 4 5 6 7 8 9 10

Making maps with a Computer Mapping Program
0 1 2 3 4 5 6 7 8 9 10

Studying Geography
0 1 2 3 4 5 6 7 8 9 10

Using animations or video games in school
0 1 2 3 4 5 6 7 8 9 10

Pre-Test Student Survey

Code _________

Thank you for completing this assessment! Your participation is very much appreciated.

Please answer the following questions:

1) The thing I liked best about this research project was:

2) The thing I liked least about this research project was:

Please rank the following activities:

Geocache at Corvallis High School
0 1 2 3 4 5 6 7 8 9 10

Using GPS units at Dixon Creek
0 1 2 3 4 5 6 7 8 9 10

Making Maps with GIS Software at OSU
0 1 2 3 4 5 6 7 8 9 10

Using GeoMapApp to explore ocean data
0 1 2 3 4 5 6 7 8 9 10

I learned the most from this activity:

I learned the most from this activity

Please put an X next to each activity you participated in:

School Visit/GPS and GIS lecture/Geocache at Corvallis High School ____
GPS Data Collection at Dixon Creek ___
GIS Mapping at OSU ___
GeoMapApp Day 1 ___
GeoMapApp Day 2 ___
GeoMapApp Day 3 __

Discussion

Figures A8.1 through A8.5 represent the students' self reported scores on interest in computer related activities; frequency and duration of participation in video game activities, experience using hand held GPS units and experience using the mapping software of Google Earth. Overall, males appear to be more interested in all the listed activities related to computers and technology, except cell phone usage and surfing the internet (Figure A8.1). Males also reported a higher frequency, number of times per week, and duration, number of hours per week for playing video games, with some males indicating they play video games daily, and some reporting more than 8 hours of game play time per week (Figure A8.2 and Figure A8.3). The majority of students reported having used hand held GPS units, and this was to be expected, as the case study activities included using hand held GPS units on Day 1 and Day 2. Males reported a higher number of total times using hand held GPS units than females (Figure A8.4). In general, males and females indicated equal number of times using Google Earth (Figure A8.5).

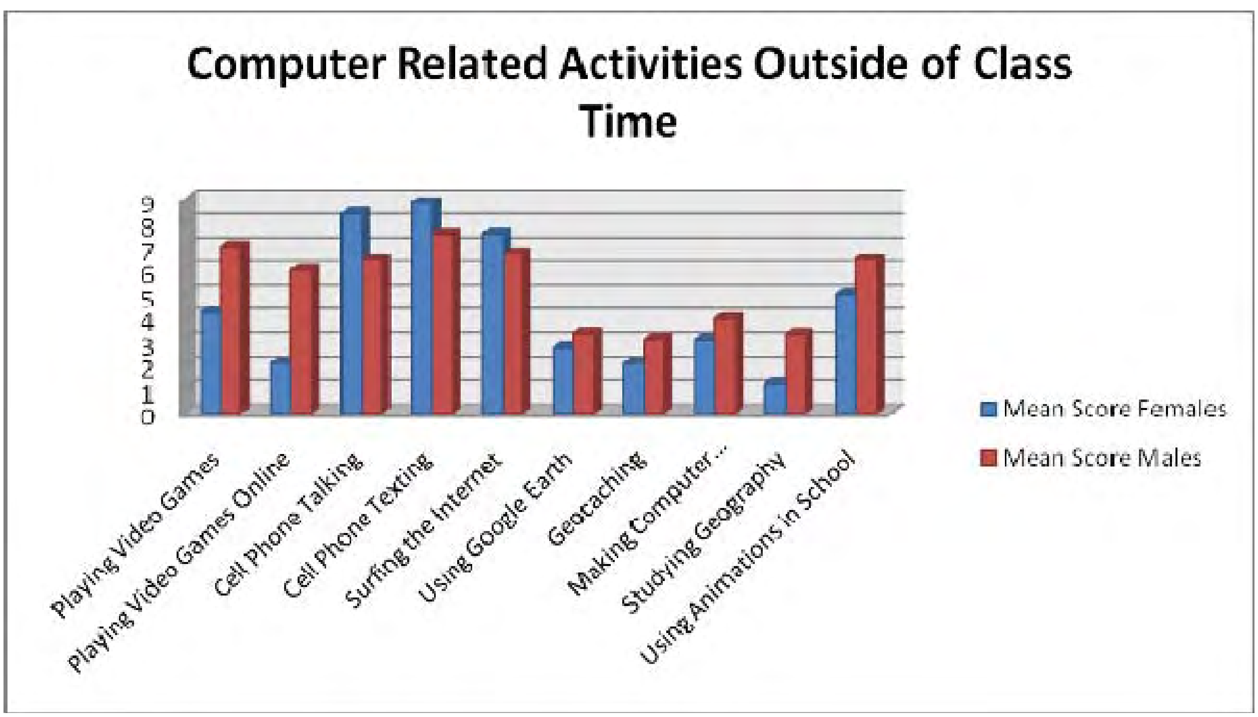


Figure A8.1. Results of questionaire assessing interest and involvement in computer related activites outside of class time, showing comparison of females and males.

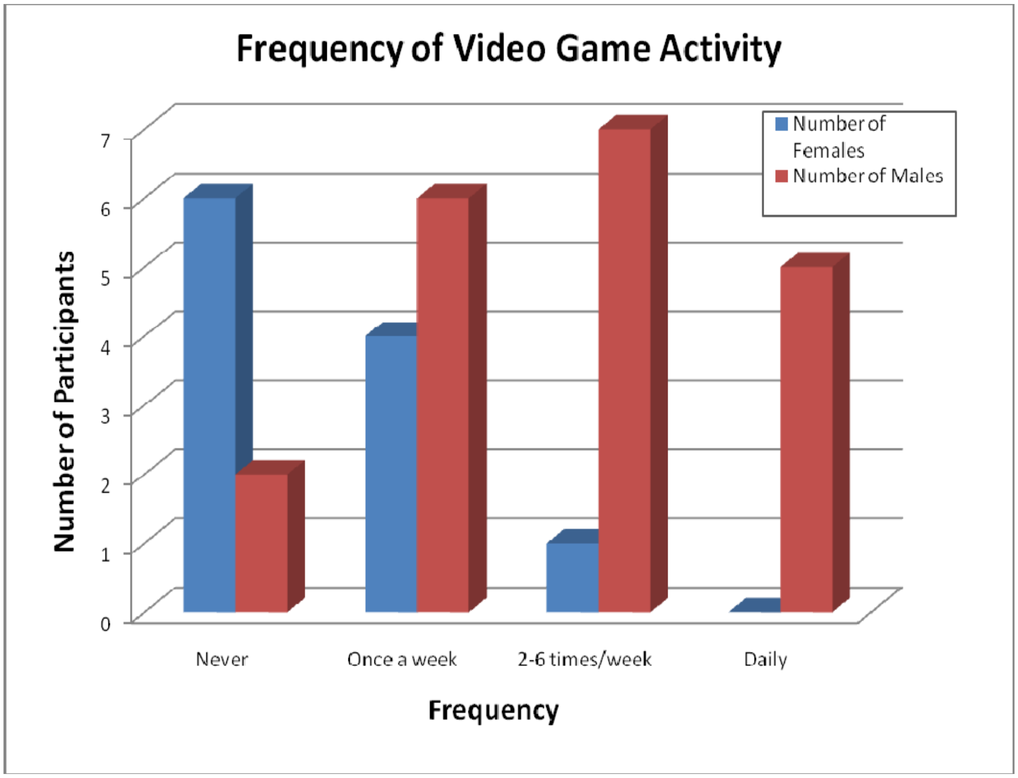


Figure A8.2. Results of questionnaire reporting frequency of video game activity, showing comparison of females and males.

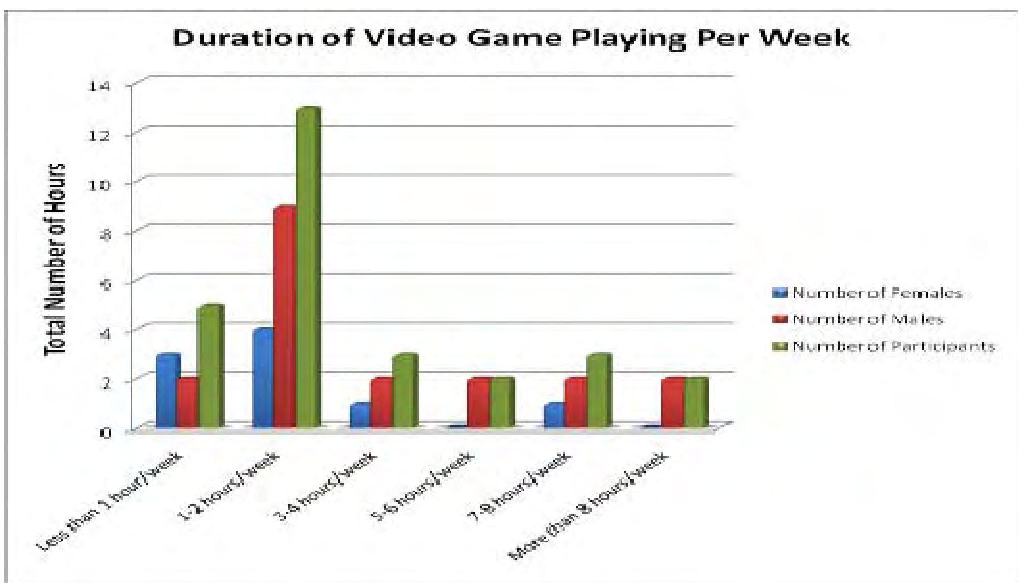


Figure A8.3. Results of questionnaire reporting duration of video game activity, showing comparison of females and males.

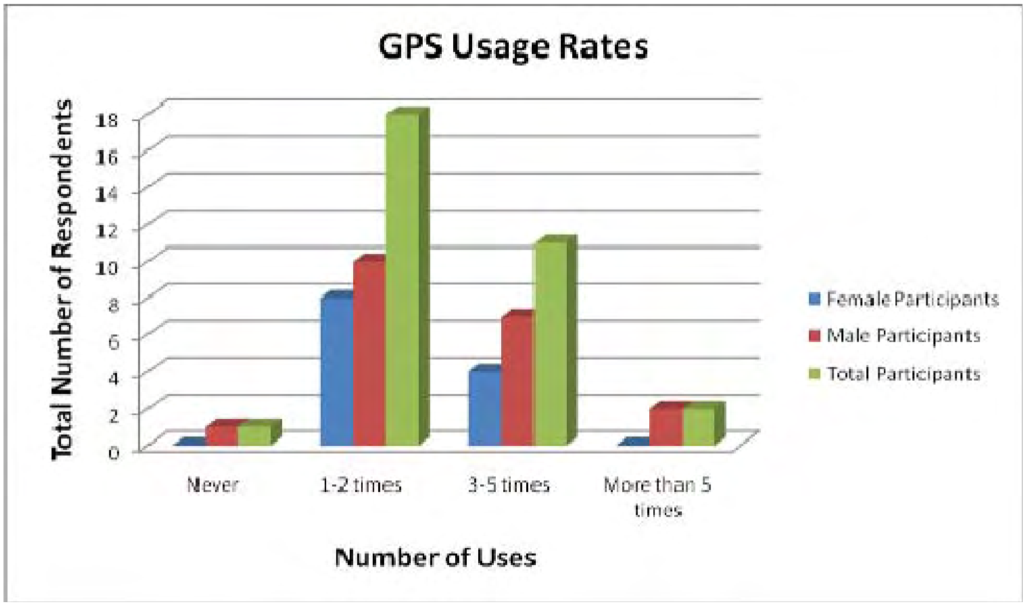


Figure A8.4. Results of questionnaire reporting number of times using a GPS hand held unit, showing comparison of females and males.

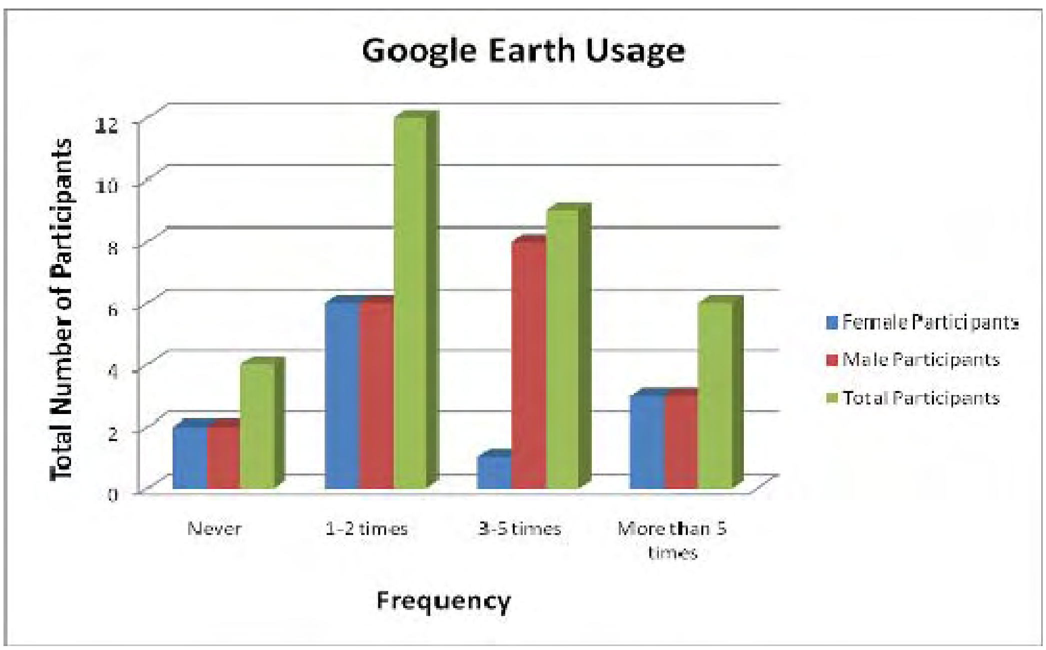


Figure A8.5. Results of questionnaire reporting number of times using Google Earth mapping software, showing comparison of females and males

Appendix 9. Detailed Summary of Student Activites.

Activities

Day 1. Classroom visit: 25 minute presentation on GIS, 60 minute practical exercises with GPS units around the Corvallis High School campus.

Day 2. Field Data Collection: 90 minute outdoor laboratory session, GPS units used to collect geospatial data at Dixon Creek.

Day 3. ArcGIS 9.1 computer session; imported data into a project, changed cartographic symbology, created jpeg map layouts.

Day 4. Pre Assessment Testing

Pre Test (Appendix 8)

1. Questionnaire to assess experience and interest with various types of technology
   a. GPS
   b. Google Earth
   c. Computer Mapping Software (e.g. ArcGIS)
   d. Video Games
   e. Animations
   f. Cell Phones

2. 28 question instrument
   a. open ended questions, multiple choice questions, matching
   b. graph interpretation, map interpretation, 2D to 3D visualization (spatial thinking), geographic literacy, mathematical skills

Day 5. Introduction to GeoMapApp: Earth Exploration Toolbox Chapters 1, 2 and 4.
Day 6. Practice with GeoMapApp:
Worksheet 1 (Appendix 4) and Worksheet 2 (Appendix 5)
1. sketch profiles of seamount chain, trench and ridge
2. describe location of seamount chain, trench and ridge
3. Whale data table; lat/long/depth
4. Average depth of whale by species
5. Describe patterns you see for each species

Day 7. Open Ended Scenario Activity (Appendix 6)
Day 8. Post Assessment Testing

Post test – The testing instrument was re-administered to the same students participants upon completion of the three classroom sessions to evaluate changes in competencies, and proficiencies in grade appropriate math, science, geography and spatial literacy skills among the students.

Post Test

1. Questionnaire of student self evaluation of like/dislikes during activities, ranking of activities; geocache, Dixon Creek field work, computer sessions including map making with ArcGIS 9.1 software at Oregon State University, GeoMapApp computer activities on a scale of 1-10. (Appendix 8)

2. 23 question instrument (repeated questions 1-23 from pre test testing instrument, Appendix 7).

Materials used during the classroom sessions included:

- Lecture of conceptual material with Powerpoint slides and visuals (globes, paper maps and GPS units).
- Testing instrument (Appendix 7)
- GeoMapApp Worksheet 1 (Appendix 4)
- GeoMapApp Worksheet2 (Appendix 5)
- Scenario (Appendix 6)

All research was granted approval on May 16, 2008, by the Oregon State University and the Institutional Review Board process of review for research involving human subjects, as Study Number 3925, *Developing Educational Tools and Integrative Experiences Via Geovisualization*. All students considered minors, under 18 years of age, obtained parental consent (Appendix 10). All students over 18 years of age indicated their permission to participate in the study with a letter of assent (Appendix 11). To protect the identities of the students and maintain confidentiality, all direct identifiers were removed from pre and post assessments and worksheets. Codes were assigned to students using a random numbers generator, and a code list was maintained separate from all documents during the classroom sessions and data analysis. The master code list is maintained in written format in a locked office and locked filing cabinet, as well as electronically on a password protected computer, separate from the assessments, analysis and access of the student researcher.

Appendix 10. Letter of Consent

Department of Geosciences
Oregon State University
104 Wilkinson Hall • Corvallis, Oregon
97331-5506
Tel: (541) 737-1201 • Fax: (541) 737-1200 • www.geo.oregonstate.edu

INFORMED CONSENT DOCUMENT

Project Title: *Developing Educational Tools and Integrative Experiences via Geovisualizations*

Principal Investigator: Dr. Dawn Wright, Geosciences
Co-Investigator(s): Michelle Kinzel, Graduate Student, Geosciences

WHAT IS THE PURPOSE OF THIS STUDY?

My name is Michelle Kinzel, and I am a researcher at Oregon State University. Along with the principal investigator, Professor Dawn Wright, I am inviting you to allow your child to take part in a research study designed to investigate the use of geovisualizations in education.

This study focuses specifically on the use of multimedia tools and data sets collected by scientists that allow for the integration of complex concepts and processes related to our ocean environment, combining oceanographic, geographic and biological data sets into an integrated computer environment. The activities and lessons written for this study encourage the use of spatial and geographic literacy skills, emphasizing the study of the oceans in ways that mirror the tools and techniques used by modern day researchers.

The goals of the study are to enhance educational curricula and encourage the development of geographic literacy and use of spatial thinking. Students will explore data sets using computer tools and gain a better understanding of ocean related spatial patterns, linkages, trends and processes on local, regional and global scales.

WHAT IS THE PURPOSE OF THIS FORM?

This consent form gives you the information you will need to help you decide whether to allow your child to participate in the classroom activities and assessments. Please read the form carefully. You may ask any questions about the research, the possible risks and benefits, your rights as a parent and anything else that is not clear. When all of your questions have been answered, you can decide if you will allow your child to be in this study or not.

WHY IS MY CHILD BEING INVITED TO TAKE PART IN THIS STUDY?

Your child is being invited to take part in this study because he/she is a currently enrolled student at Corvallis High School. We are designing lessons that will be used in grades 9-12, incorporating cutting edge techniques and scientific data sets from researchers in oceanographic and geographic scientific communities and wish to test the effectiveness of our techniques and methods.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

If you choose to allow your child to participate in this study during regular class time, your child will explore scientific data sets with multimedia tools in the computer lab at their school. The assessments will consist of questions designed to measure the use of spatial thinking skills and acquisition of geographic literacy. The assessments will be anonymous, and no identifiable data will be used in the study. There will be no names or student identifiers collected, and the assessments examined by the student researcher on the project will be completely anonymous.

If you agree to allow your child to participate in the study, their involvement will last for approximately three classroom sessions, for a total of 285 minutes.

WHAT ARE THE RISKS OF THIS STUDY?

The possible risks and/or discomforts associated with the procedures described in this study include:

The only risks anticipated are minimal risks during the testing session associated with normal student activities of test taking and using a computer terminal in a secure classroom.

A minimal risk is involved in protecting the confidentiality of the assessments (testing scores) of the students involved in the study.

WHAT ARE THE BENEFITS OF THIS STUDY?

Your child will receive the direct benefit of using multimedia cutting edge technology and use of real world scientific data from participating in this study. Additionally, we hope that the information gathered from this study will improve the quality of science education for grades 9-12.

WILL MY CHILD BE PAID FOR PARTICIPATING?

Your child will not be paid for being in this research study.

WHO WILL SEE THE INFORMATION I GIVE?

The information collected during this research study will be kept confidential to the extent permitted by law. To help protect your confidentiality, we will:

- Ensure that the assessments and analysis are kept separate and in a secure location, i.e., only on a password secured laptop and locking filing cabinet maintained in the research institutions laboratory at Oregon State University.

- Refrain from collecting student names and assign random numerical identifiers to all assessment materials.
- Use random numerical identifiers or pseudonyms on assessment materials if the results are published in a scientific journal, at a professional science meeting, or in a thesis manuscript.
- Keep code lists and data files in separate secure locations. We will keep one copy of the code list on a password protected computer and another hard copy in a locked file cabinet.
- Use and protect all computer passwords and lock combinations/keys.

If the results of this project are published student identities will not be made public, nor will the results be tracked or related to individual names before, during or after the research. The student researcher will not have access to individual student names while assessing, analyzing or reporting results from this study.

DO I HAVE A CHOICE FOR MY CHILD TO BE IN THE STUDY?

If you decide to allow your child to take part in the study, it should be because you approve of your child participating in an educational project.

Your child will not be treated differently as a student if you decide to not allow them to take part in the study. Students not granted permission to participate in the computer laboratory sessions will attend their regularly scheduled classroom sessions.

WHAT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact:

- Principal Investigator: Dawn Wright
  541-737-1229
  dawn@dusk.geo.orst.edu
- Co-Investigator: Michelle Kinzel
  541-737-8818
  kinzelm@geo.oregonstate.edu

If you have questions about your child's rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, at (541) 737-4933 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to allow your child to take part in this study. You can receive a copy of this form by contacting Michelle Kinzel, kinzelm@geo.oregonstate.edu.
Parent/Guardian Name/ Participant's (Student) Name (printed):

____

____ ______________________________

(Signature of Parent/Guardian) (Date)

Appendix 11. Letter of Assent

Department of Geosciences
Oregon State University
104 Wilkinson Hall • Corvallis, Oregon 97331-5506
Tel: (541) 737-1201 • Fax: (541) 737-1200 • www.geo.oregonstate.edu

ASSENT DOCUMENT

Project Title: *Developing Educational Tools and Integrative Experiences via Geovisualizations*
Principal Investigator: Dr. Dawn Wright, Department of Geosciences
Co-Investigator(s): Michelle Kinzel, Graduate Student, Department of Geosciences

We are doing a research study on the use of multimedia tools in high school curriculum. We are trying to find out how to improve educational practices using computer tools, or geovisualizations.

This form contains information about the study, so that you can decide if you want to be in the study or not. You can ask any questions. After all of your questions have been answered, you can decide if you want to be in this study or not.

If you decide that you want to be in this study, we will ask you to complete hands-on lessons using the computer lab at your school and oceanographic data sets. We will meet for 3 class periods of 95 minutes each.

We want to tell you about some things that might happen to you if you are in this study and what to expect. You will be expected to work on the computers for some or all of the 90 minute class session.

If you decide to be in this study, some of the expected benefits include an improvement in your geographic knowledge, spatial thinking skills and/or computer skills. We are not certain these improvements will occur. We may also discover methods and information that will help us design effective tools and lessons for use by other students and teachers.

You do not have to take part in this study if you do not want to. You can use the class time to meet with the teacher's aide in your regular classroom instead of in the computer lab.

When we are done with the study, we will write a report about our observations and results. We will not use your name in the report.

You do not have to participate in the study, the choice is yours. If you agree to begin the study but want to discontinue during the process, you merely need to inform one of the instructors.

If you want to be in this study, please sign your name.

I, ______________________________________, want to be in this research study.
(Print your name here)

_______________________________________ ____________________
(Sign your name here) (Date)

Oregon State University • IRB Study #:3925 Approval Date: 05/16/08 Expiration Date: 05/15/09