Using Geovisualizations in the Curriculum: Do Multimedia Tools Enhance Geography Education?

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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 under utilized. This paper examines the application of multimedia technologies and interactive geovisualizations based on National Geography Standards 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 such as serious games.

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. An example would be a map representing the migratory route of the gray whale along the Pacific Coast of North America (Figure 1).

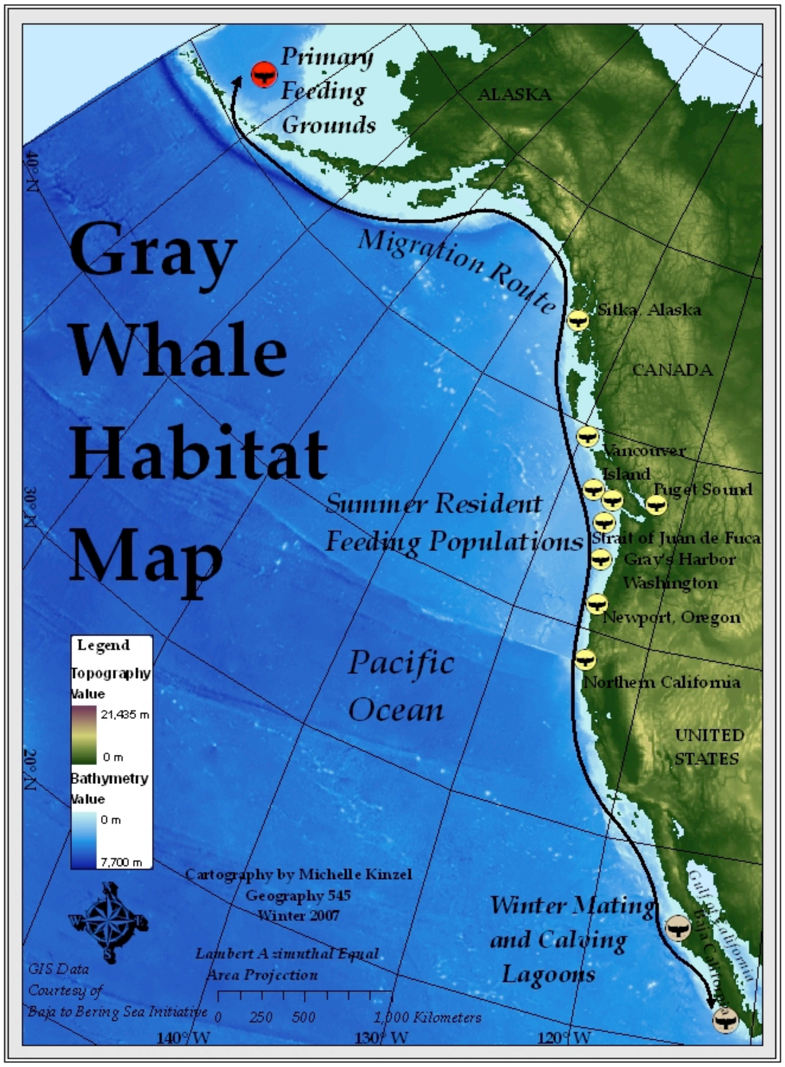

Figure 1. GIS Map representing migratory route of gray whales in North America, an example of a static geovisualization. Created with ArcGIS 9.1.

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. Examples of dynamic earth science tools include the depth profiles created in GeoMapApp, displaying portions of the seafloor along a transect as chosen by the user in a graphical output (Figure 2).

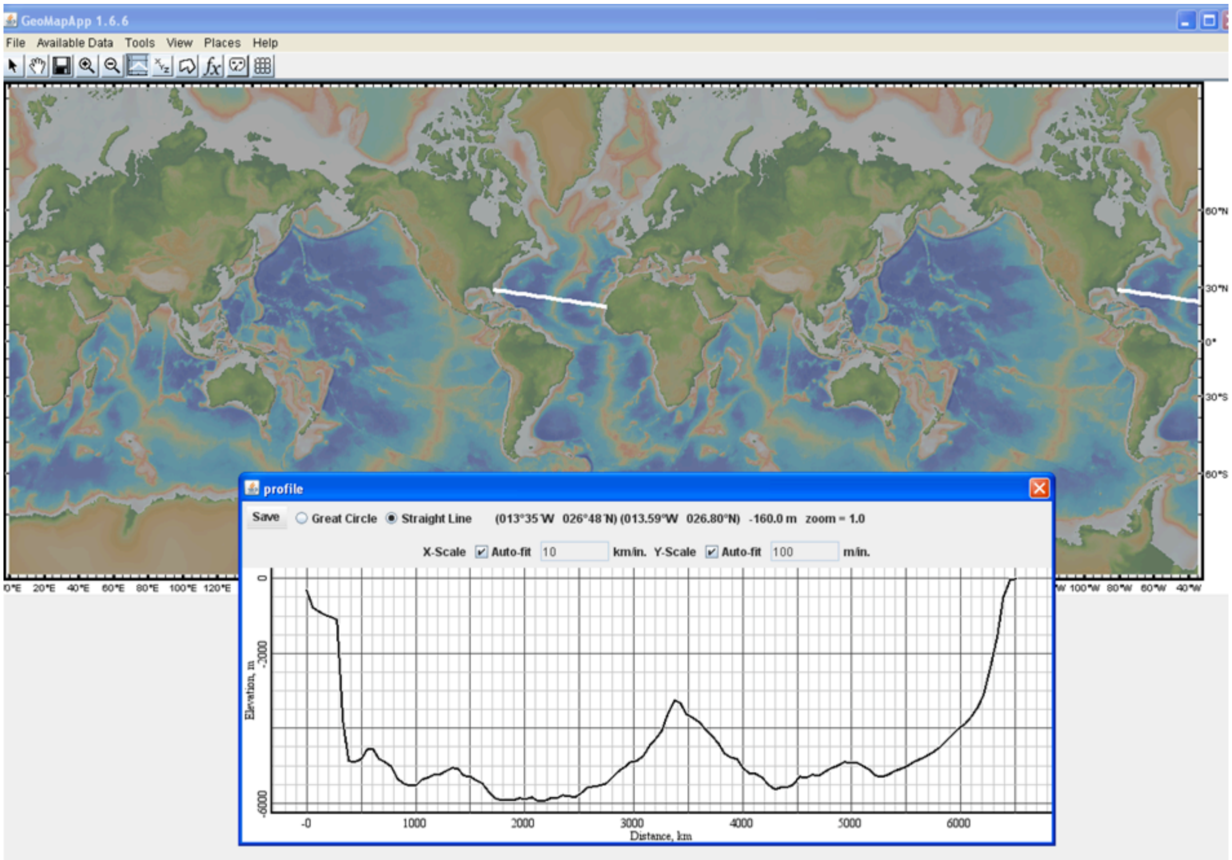

Figure 2. Screen shot from GeoMapApp, showing world geographic map output and profile of seafloor across an imaginary transect line between North America and Africa, an example of a dynamic geovisualization.

GeoMapApp is a data exploration and visualization tool that allows access to a variety of data sets in an integrated mapping application developed at Lamont-Doherty Earth Observatory (http://www.geomapapp.org/).The most effective tools for teaching are interactive ones, such as 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 the activities of the student (Solem, et al., 2009) Active learning is based upon the constructivism theory, which states that learning is a process in which the learner actively constructs knowledge. 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). For Earth science teachers, the digital age offers a plethora of spatial tools and techniques for implementing active learning into existing curricula. The use of geovisualizations is an ideal way to address core Earth science and geography concepts, meet standards based curriculum development goals and engage students in active learning that is engaging and effective.

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 described geovisualization as both a research focus and a set of tools that held 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. 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.

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. 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.

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.

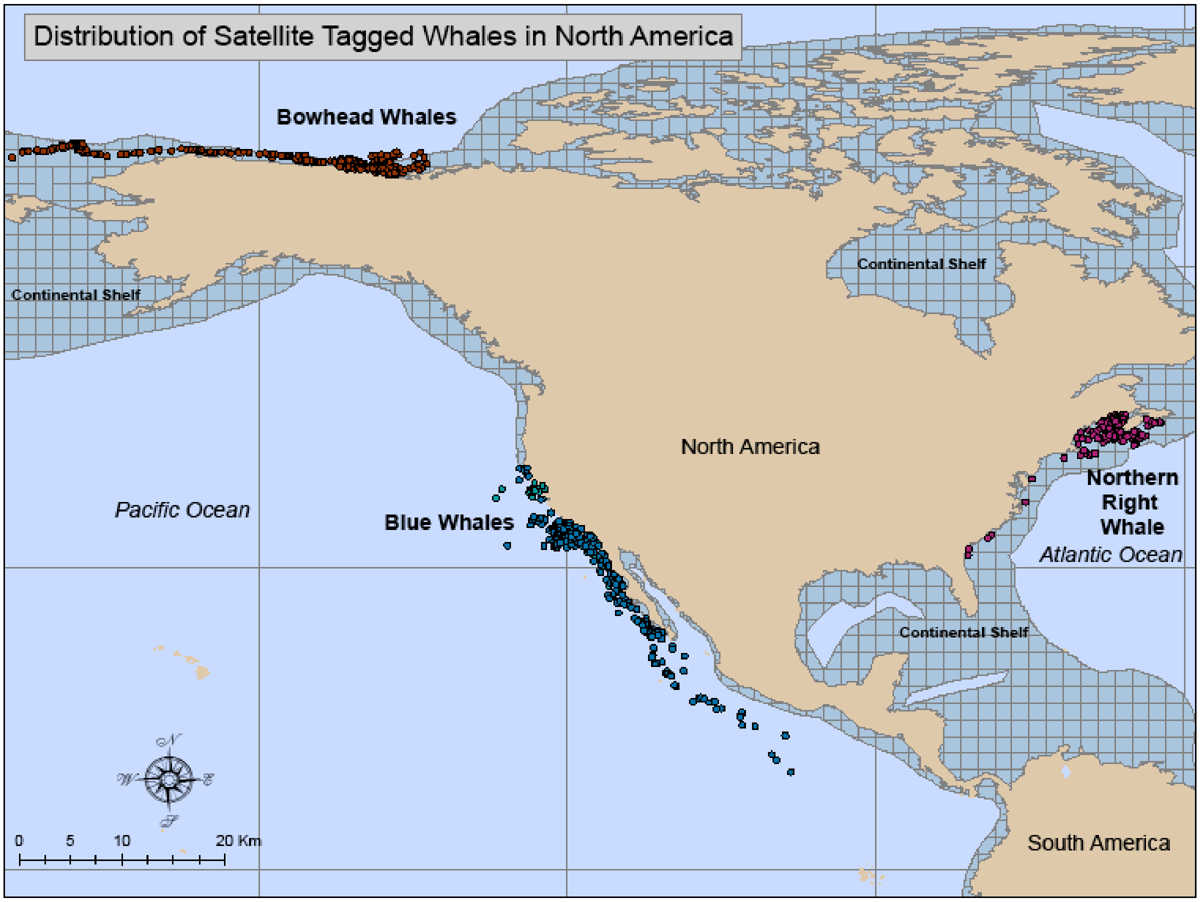

Figure 3. GIS created map showing distribution of 3 species of whales, Bowhead, Blue and Northern Right whales, as determined from satellite telemetry tags, and their spatial relation to the continental shelf and North America. Created with ArcGIS 9.1. Marine Mammal Data courtesy of Marine Mammal Institute,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

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 1 details 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 1. Using Multimedia Tools in curricula and pedagogical applications according to Bloom's taxonomy stages. (GMA† GeoMapApp, GIS‡ geographic information systems such as ArcGIS, AEJEE).

		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			❋	❋

Multimedia has the advantage of being adaptable, engaging and accessible to today's technology savvy students. With the use of computer assisted technology, students can use mapping environments and animations to explore spatial patterns, linkages, trends and processes on a local, regional or global scale. This interactive and inquiry based learning allows students to develop a complex and integrated understanding of the data sets and the spatial aspects related to the data. Experience with the technology allows students to participate in active learning, directing the learning process according to their thought processes. The trend shown in Table 1 highlights the nature of highly interactive tools, namely that animations and mapping software engage the learner in the process to a high degree, and thus address more of the learning skills and levels of learning as defined in Bloom's Taxonomy.

Applying Data Sets and Imagery in Problem Solving Exercises

As students perform the classic GIS related skills, manipulating, modifying, querying, analyzing and exploring spatial data sets, they acquire a richer understanding of the concepts and content of material. The interactive nature of a GIS supports the learning process (Medyckyj-Scott, 1994; Fink, 1999). Problem based learning is ideal for the use of GIS (Carver, Evans, and Kingston, 2004; Drennon, 2005) as well as fundamental educational objectives of building competency and literacy (Lo, Affolter, and Reeves, 2004).

Introducing the elements of scientific inquiry into problem based activities introduces inquiry based learning into the curriculum. Teaching strategies that utilize inquiry-based learning (Mazur, 1997) emphasize higher order thinking processes such as making observations, presenting questions, data analysis, predictions, can communication of ideas (Brunkhorst, 1996; National Research Council, 2000).

Google Earth makes aerial photography and remote sensing applications feel more user friendly, and therefore accessible to users, particularly students who have grown up in the digital age. The ability to observe places with a birds eye perspective adds a dimension to the familiar, and encourages new spatial thinking patterns.

Pedagogical Goals

Particularly in educational settings, the potential of applying tools and techniques in problem-solving exercises remains largely under utilized. 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, et. al. 2000). 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. 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 integration of 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 extent beyond a narrow range of subject matter.

The rapid proliferation of computer technology has improved the options available for 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).

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. The world is becoming increasingly interconnected, globally, economically and culturally. Making decisions about where to live, where to work, where to spend leisure time are all reliant upon knowing world geography. 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 18 Standards, all benchmarked according to specific grade levels (Geography for Life, 1994). These recommendations for a geographically literate citizen are hallmarked according to competencies to be demonstrated at 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 defined 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 5 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). Table 2 illustrates the 18 National Geographic Standards, grouped under the six essential elements and 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 4 types of geovisualizations considered in this paper.

Table 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 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
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
Standard *The geographically informed person knows and understands:*	**Geovisualization Static**	**Geovisualization Dynamic**	**Mapping Software**	**Serious Game**

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

Summary

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 18 geography standards grouped according to the six essential elements. Each tool type is appropriate within an 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).

From an educator's perspective, the main goals for today's classroom sessions are to teach to standards based learning objectives. The current educational administration is focused on meeting national and state objectives. In order for change to occur, and educators to embrace new tools or techniques in their curricula, there must be a means of assessing competencies and mastery of learning objectives. The standards vary widely among states, counties and even school districts, but all educational systems are looking towards the effectiveness of tools in meeting standards and teaching skills. As shown in Table 2, geovisualizations can be used to address both of these needs.

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. And some standards are suitable for the use of static geovisualizations such as maps and diagrams, as exemplified by the Standard #6 which emphasized culture and experience. 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. 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.

Ongoing Research

Our society has changed dramatically over the past few decades, and technology permeates every aspect of our culture and daily lives. 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, ecologists studying the environment, engineers predicting effects of forces, and numerous science simulations are accepted in the workplace (Prensky, 2007). Yet 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 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).

What can we do to begin educating our 21st Century children with 21st Century technology tools? We must address the barriers to adoption of serious games in curricula; lack of money, lack of time, lack of knowledge or training, lack of technology and a common belief that serious games cannot address standards based curricula. The political factors will continue to be pressing issues; funding, time and technology 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.

As a case study into the effectiveness of geovisualizations in education, the authors of this paper have begun working with high school students, teaching GPS skills, geographic information system basic skills and using mapping software to teach concepts related to geographic literacy. Pre and post assessments, as well as producible materials from instructor led computer sessions are being analyzed to determine the changes in spatial thinking, geographic literacy, and ultimately the effectiveness of using geovisualizations in education. The results will be used to create geovisualizations specifically designed to meet educational goals, encourage spatial thinking and increase geographic literacy in conjunction with other core content subject areas such as science and math.

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