The Use of Virtual Globes as a Spatial Teaching Tool with Suggestions for Metadata Standards

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Abstract

Virtual Globe software has become extremely popular both inside and outside of educational settings. This software allows users to explore the Earth in three dimensions while streaming satellite imagery, elevation, and other data from the Internet. Virtual Globes, such as Google Earth, NASA World Wind, and ESRI's ArcGIS Explorer can be effectively used in standards-based, inquiry-driven geography lessons. With some practice, mashups (using data from more than one source to create new data) can be constructed for practically any application or area of interest. Educators who have not already begun to use these tools may wish to investigate them to help their students to think spatially by investigating processes and places on the Earth's surface in a three-dimensional visualization environment.

Key Words: *Google Earth, spatial literacy, metadata standards, geography education, remote sensing*

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Introduction: An Overview of the Importance of Spatial Thinking

It has been said that, "...In terms of its power and pervasiveness, spatial thinking is on a par with, although perhaps not yet as well recognized and certainly not as well formalized as, mathematical or verbal thinking..." (National Academy of Sciences 2006). Unfortunately, there is no clear consensus about spatial thinking or spatial literacy. Researchers use related terms, such as spatial ability, spatial concepts, spatial reasoning, spatial cognition, spatial intelligence, environmental cognition, mental and cognitive mapping, and mental maps (Eliot 1987; Gardner 1983; Golledge and Stimson 1997; Gould and White 1974; Kitchin 1994; Kitchin and Freundschuh 2000; Newcombe and Huttenlocher 2000; Portugali 1996; Tversky 2000a, 2000b). Spatial thinking is multifaceted in its operation. Just as there is no single recipe for how to think verbally or mathematically, there is no single way to think spatially. Instead, the process of spatial thinking comprises broad sets of interconnected competencies. Spatial thinking includes spatial knowledge—of symmetry, orientation, scale, distance decay, and other concepts. It also includes spatial ways of thinking and acting, such as understanding change over space versus change over time and recognizing patterns in data. Spatial thinking also includes spatial capabilities, such as the ability to use statistical data and GIS (geographic information system) software and tools. Most importantly, spatial thinking and competencies are an important part of the educational curriculum at all levels, and they can be taught and learned.

As educators, it is our task to convey spatial concepts and encourage spatial thinking to our students. The question remains—how can this be accomplished? In the recently published *Support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K–12 Curriculum*, the following was offered by the Geographical Sciences Committee of the National Research Council (the committee):

> Given the need for increased scientific and technological literacy in the workforce and in everyday life, we must equip K–12 graduates with skills that will enable them to think spatially and to take advantage of tools and technologies—such as geographic information systems (GIS) for supporting spatial thinking. (p. 13)

The committee's charge contained two questions, the first of which was intended to generate recommendations for levels of technology (hardware and software), system supports (for example, teaching materials), curriculum scope and sequence (for example, the role of necessary precursors), and preservice and in-service training. The second question was intended to generate recommendations based on an assessment of theoretical and empirical approaches in psychology and education relevant to the development of knowledge and skills that underpin the use of GIS. Further, the committee developed two additional questions:

1. What are the nature and character of spatial thinking?
2. How does the capacity for spatial thinking develop and how might it be fostered systematically through education and training?

The committee came to believe that spatial thinking is pervasive; it is vital across a wide range of disciplines of practical and scientific knowledge,

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yet it is under-recognized, undervalued, underappreciated, and therefore, underinstructed. Despite the practical importance of both historical and contemporary spatial thinking, the committee recognized that scientists and educators have not yet clearly identified and described the operations of spatial thinking. Without a clear understanding of the nature and character of spatial thinking, it is impossible to design instructional systems and technologies to support it. Students need to know the concepts that are the "building blocks" for spatial thinking. The general aspects of spatial concepts, such as symmetry, isomorphism, reflection, orientation, rotation, and function, are present in numerous disciplines. There are also spatial concepts that are tailored to a particular discipline, such as relative versus absolute distance, small versus large scale, and distance decay in geography (National Academy of Sciences 2006).

Could it be that one type of educational tool could assist in all of these desired areas of learning? Many have advocated that a tool created specifically for spatial analysis should be used to *teach* spatial analysis. That tool, GIS, has been successfully used in formal and informal education around the world for at least fifteen years to teach concepts such as ecoregions, agriculture, population characteristics and dynamics, historical migration, natural hazards, and many more. Since 2000, Web-based mapping tools and Internet-GIS have been increasingly used as a complement to desktop GIS due to its ease of use, availability, and functionality (Kerski 2008).

One type of Internet-based GIS is virtual globes. The most commonly used virtual globes are World Wind from NASA, ArcGIS Explorer from ESRI, Skyline's TerraExplorer, and Google Earth from Google. Of the eighteen geography standards, the elements of *The World in Spatial Terms, Places and Regions, Physical Systems, Human Systems, Environment and Society*, and *The Uses of Geography* are the standards that the uses of virtual globes seem to most easily address. Virtual globes also provide a practical application and tool for remote sensing, the study of the Earth using sensors aboard spacecraft and aircraft.

Virtual Globes as Teaching Tools

What Are Virtual Globes?

Virtual globes are so named because of their approach to visualizing the Earth as a three-dimensional globe that one can "fly" above. Virtual globe software runs with two main components—a moderately-sized software program and spatial data that is streamed "on the fly" from the Internet as the program is used. The streaming data includes commercial or public domain satellite imagery, aerial photographs, elevation data from the Shuttle Radar Topography Mission, along with points, lines, and polygonal data that include a range of types—from transportation routes and hydrography networks to buildings. Because the file sizes of these data sets are quite large, a fast broadband connection to the Internet is absolutely essential for the successful educational use of virtual globe tools.

Using the software and the streaming data together, the geography educator and student can view nearly every location on the Earth's surface from any angle and from any distance. The tools simulate flying above the landscape as if the user were in their own personal spacecraft. At any point, one can zoom, pan, or tilt the Earth view for a 3D perspective and stop at key points of interest.

Depending on the area examined, one might be able to see individual trees, automobiles, and other detailed information that one would expect while viewing 0.61-meter resolution Digital Globe QuickBird satellite imagery or .25-meter USGS (U.S. Geological Survey) digital othorphotoquadrangle (DOQ) aerial photography. In other areas, however, the resolution may be based on 30-meter Landsat imagery and is only suitable for medium-resolution investigations such as regional land use and watersheds.

These data sets and three-dimensional viewing capabilities have been available to users of GIS and remote sensing software for a number of years. However, virtual globe software brings these data sets and fly-by capabilities to the educator without the time and financial investment in GIS and remote sensing software. An added bonus is the relative ease with which applications can be customized and shared with others in remote locations. While the spatial analysis tools available through GIS and remote sensing software are largely absent in virtual globe software, the ease-of-use, low cost, burgeoning availability of data sets, and extremely engaging, and often addictive, nature of virtual globes merit their consideration for use in the geography classroom at all levels. In addition, virtual globe software is increasingly intertwined with traditional GIS. For example, one can bring digital spatial data on natural hazards in GIS format directly into ArcGIS Explorer for further analysis. Or, one can export a GIS map into a format directly readable in Google Earth.

An Example of Virtual Globes: Google Earth and Its Three Versions

Google Earth has become the world's most popular virtual globe software. It has spawned a very large, active user community that extends far beyond the educational system. Indeed, one could argue that it has exposed more of the general public in a few years to the power of using spatial data to examine the world than GIS and remote sensing had done in thirty years. Google Earth is not a GIS, but because of its ease of use, its ability to easily incorporate data sets created by users, and Google's large presence in society, it has reached more people.

The Google Earth client is available in three different versions, all available from *http://earth.google.com*. The standard Google Earth is free and runs on both the Mac and PC platforms. Google Earth Plus costs $20, runs on a PC, and allows the user to add global positioning system (GPS) coordinates to the 3D map. Garmin and Magellan GPS coordinates can be directly input via a cable, while output from other GPS receivers can be used if the data are saved via a .gpx or .loc file. Spreadsheets of 100 points (using the

Plus version) or 2,500 points (using the Pro version) also can be imported and mapped. These spreadsheet locations can be street addresses or latitude and longitude coordinates.

Google Earth Pro costs $400, runs only on a PC, is faster, streams the highest resolution satellite images, allows for higher-resolution prints, and allows the user to add many types of data, including georeferenced data layers traditionally only viewable through GIS software. Pro allows the user to purchase modules to make movies, print larger images, import GIS data, and add data on shopping centers and vehicle counts. These are the kinds of data that are typically either unavailable or else difficult for the educator to obtain, yet are the types of data that can excite students to learn more about the Earth. The Google Earth *FAQ* (frequently asked questions) page provides details on minimum system requirements: *http://earth.google.com/faq.html.*

User-acquired images can be added manually to the free version of Google Earth, but the Pro version makes overlaying much easier. This is because the Pro version can read the coordinates from image headers (or embedded information such as in GeoTIFF images). Google's acquisition of SketchUp allows three-dimensional building models to be created and placed on the virtual 3D landscape.

One of the most exciting developments in 2006 was the announcement that, through the Keyhole-Google Education Initiative, a faculty member or school administrator can obtain a free license of Google Earth Pro for one year. Dennis Reinhardt is the point of contact for this agreement, and can be reached at den@google.com.

Mashups and the Keyhole Community: Keyhole Markup Language, Mashups, and Mapping Hacks

When Google bought Keyhole in 2004, Google acquired the Keyhole Markup Language (KML). KML is an eXtensible Markup Language (XML) grammar and file format for modeling and storing geographic features such as points, lines, images (raster data), and polygons for display in Google Earth. KML files, and a compressed version called .kmz, provide the locations that the creator wants the user to go to, the data, the scale, and other characteristics of the user-data interactive experience. Because KML is open source, it has been used to create Google Earth and Google Maps "mashups" that combine the capabilities of Google Earth (or maps) with other applications.

The open-source nature of Google Earth has led to thousands of "map mashups," which are Internet applications that combine the content from more than one source, one of which is usually a Web-based mapping application. These include everything from crime locations to determining the precise location of the other side of the Earth from any given spot.

It has been said that Google Earth "... is an amazing array of both satellite imagery with the potential for customizable mashups that are seemingly endless in its applications..." (Dragan 2005). Google Earth is making people aware of the power of mapping and is spawning legions of developers who are tagging data with location information for online posting. At first this was being done mostly by amateurs who create services simply because they are useful. As Jeremy Crampton (2006), professor at Georgia State University, notes "Not all mashups use maps, but it's surprising how many do."

Map hacking is another development, in large part due to the influence of Google. Map hacking is not used here in the negative sense, but rather refers to adapting and developing mapping software for one's own purposes. According to Crampton (2006), "...by early 2006, there were already more than 250,000 members of the Google Earth bulletin board, with more than 4,500 joining every day. This number does not even represent the total number of users, but rather, people who take the time to register."

Data Quality: Metadata Standards

Fundamental to the effective use of data is to know its source, date, and accuracy, and provide necessary background on its usefulness and origination. When applied to spatial data, these characteristics are referred to as metadata (commonly referred to as "data about data"). In the early days of GIS, there were so few sources of spatial data, such as USGS-NASA Landsat, and TIGER (Topologically Integrated Geographic Encoding and Referencing) files from the U.S. Census Bureau, that there was little need for metadata. Today, metadata is an integral part of our daily activities. It is so important that we make a point of creating and updating our metadata on an almost daily basis. Many of us may think that we are creating new sources of *data*, but in fact, each source of data automatically creates and demands associated metadata. Even outside of GIS, the myriad of spreadsheets, documents, diagrams, and reports are immediately in need of supporting metadata—everything that is necessary to locate, identify, understand, source, and access our new creation after it is completed.

With all of the capabilities of virtual globes, the downside is that this mammoth grassroots effort of creating virtual-globe compatible maps yields much duplication, as well as much undocumented content; that is, a lack of metadata. For example, numerous crime applications now exist within Google maps, but they seem to be drawing from different sources, with much missing data in terms of space and time, and no comprehensive site where an educator would know that he or she is examining *all* of the crime for a certain city over a certain period of time. This makes it difficult to determine not only the true crime rate but also to compare crime between cities.

Having access to metadata is crucial to the understanding of the lineage of data and potential weaknesses and/or limitations in data collection and application. Complete and accurate metadata will only remain that way if it is *always* accurate. Without metadata it is nearly impossible to understand whether data is of any value—or, more simply, to distinguish "good" data from "junk" data. Allowing students to use data in an educational setting that has

errors or other limitations could negatively impact learning by creating negative attitudes about spatial data. Functional metadata for educators need not necessarily meet the Federal Geographic Data Committee's full metadata standards to be useful in the classroom, however. There are several key components to metadata that provide the educator sufficient information about the quality of data to understand whether the data sets are useful to meet the intended goals and objectives and not compromise the student's interest and learning experience. These include:

Identification. Basic information description about the dataset, including geographic location, source of the data (such as data collector), time period of data collection, and any specific parameters for acquiring and/or using the data.

Spatial Reference Information. Such detail is not typically anticipated or expected with data sets utilized as part of virtual globe software, but the description of map projection or coordinate system details can be helpful if visual errors are detected by the user. Rather than dismiss the data as invaluable or inaccurate, flaws in spatial data conversion or projection can be insightful and reinforce projection systems to students. In fact, data sets with known spatial errors can be used as a challenge to understand and explain why errors in the data are visually identifiable.

Data Details. Attribute details within a GIS are critical to identify and understand tabular data retained in the system and how such data can be used to manipulate and manage maps. Definition of field names and a description of attributes and their values is helpful to understand underlying data. With currently limited capabilities of virtual globes to use attribute details this area of metadata is relatively less applicable, but as virtual globe capabilities are enhanced and the virtual globe software becomes closer to a true GIS, information about entities and attributes will be extremely important. Spatial data organization also can be an important component of data details such as understanding the types and number of spatial objects to help ensure data set integrity and completeness. Understanding original basemap representation, such as raster or vector, can also be insightful regarding potential data conversion errors and data utilization problems.

Distribution Information. Details about data set availability can be useful to help ensure compliance with copyright laws, any limitations on using the data set imposed by the author/originator/owner (such as restrictions on redistribution), and any potential fees associated with using and/or circulating the data set.

Data Quality. Perhaps most important of all metadata components is the availability of an assessment of the quality of the data set. Such details can include positional (x, y, z) accuracy and details regarding precision of collection, completeness (including geographic and/or categorical omissions), integrity, original sources of information, and data collection methods (including sufficient details to understand the origination and manipulation through the data lifecycle).

Metadata Creation. An often overlooked component of metadata is having some idea when and how metadata themselves were created. Metadata created and maintained during the data collection process are more valuable than metadata assembled months after a data set has been collected, reviewed, and published.

Using data just because it is available can pose more difficulties and raise more questions—or inhibit certain questions from being asked—than the data may be worth. It is important to have some idea about the quality of the source and the intended application of any data used in any context, and the educational setting is certainly no different.

Applying Virtual Globes in the Classroom

From our vantage point as educators, virtual globes are still primarily visualization tools, but probably the most powerful and useful visualization tools ever created. However, they are rapidly becoming powerful tools for importing numerous formats of spatial data to allow users to visualize spatial relationships that may be present. While lacking the functionality of GIS, virtual globes provide an excellent first step into geotechnologies. The use of virtual globes could naturally and easily lead students to begin asking the questions that only a GIS can help them find answers to, such as "how many earthquakes have occurred in the last month that are within 100 kilometers of this landform that I am currently examining?" Virtual globe software in the hands of a skilled teacher can bring geographic inquiry to life—asking geographic questions, acquiring geographic resources, exploring geographic data, analyzing geographic information, and acting on geographic knowledge. This engagement with the geographic inquiry process could also *prepare* students to more effectively use more robust geotechnologies such as GIS, remote sensing, and GPS. Visualizing spatial scales, patterns, and themes in virtual globes meshes with the National Academy of Sciences' call to think spatially. In *Learning to Think Spatially*, the Academy suggests that people draw upon strategies that emphasize the use of spatial thinking to carry out projects. Users of the virtual globes set ideas into spatial contexts, seeing similar things as being close together and dissimilar things as far apart. They draw diagrams and graphs. They look for patterns and note outliers (anomalies) from the patterns. They look for clusters. They even use statistical analyses to test for spatial relationships. They look for relationships among different spatial patterns. They disentangle change over space from change over time. In each case, there is interplay between thinking and acting, between ideas and their representation, between expression for one's self and communication and dissemination to others. The educational challenge is to teach students strategies for spatial thinking; to teach *how*, *where*, and *when* to use them; and to

convey a critical awareness of the strengths and limitations of each strategy (National Academy of Sciences 2006).

Virtual globe software can be effectively used in standards-based geography teaching. Virtual globe software and data teach students how to use maps and geographic representations, tools, and technologies (Standard 1), how to analyze the spatial organization of environments on the Earth's surface (Standard 2), and how to interpret the present (Standard 18). For example, biomes and ecoregions (Standard 8) are easily seen in virtual globes from the vegetation characteristics that are evident in the satellite imagery. The physical and human characteristics of places can be explored (Standard 4), and if used together with ground photographs and text about the places, the processes that shaped the evident patterns can be understood (Standard 7). These tools make it clear that human populations have deeply impacted the Earth's surface (Standard 14) and are not distributed evenly across the Earth's surface (Standard 9). The 3D capabilities drive home the point that topography is an enormous influence on settlement as well as on agriculture and riverine systems (Standard 12). Virtual globes can be used to investigate almost anything and enhance lessons about urban sprawl along interstate highways, the folds of an anticline, or the forms of a river delta. They can be used to investigate a site that students are traveling to on a field trip, the location of a news story, or the route of a historic or present-day explorer. The pyramids of Giza, Mount Everest, and other real places can be examined with stunning detail.

Increasingly, spatial data is being served on the Web in formats that virtual globes can easily read. One example is examining the patterns of earthquakes by using USGS near-real-time earthquake data on *http://earthquake.usgs.gov/eqcenter/recenteqsww/catalogs/* (Standard 7) (Fig. 1). Another example is examining USGS near-real-time stream gage information on *http://water.usgs.gov/waterwatch/kml.html*, which can help students understand the response of rivers to rainfall, snowmelt, and drought (Standard 7).

Virtual globes can also be used to compare historical spaces and places to their present-day manifestations (Fig. 2) (Standards 17 and 18), such as through the Atlas of Victorian London on *http://www.victorianlondon.org/googleearth.htm*. Much more than maps, these resources often include links to historical texts and photographs (Figs. 3 and 4).

How to Get Started

The geography educator could start by installing Google Earth, NASA World Wind, and/or ArcGIS Explorer and allowing students to begin exploring the world. Each has its advantages. Google Earth's chief advantage may be its speed and high resolution satellite imagery. NASA World Wind's chief advantage may be its inclusion of USGS topographic maps and near-real-time cloud cover and data from other satellilte sensors. ArcGIS Explorer's advantage may be the ability to use many types of globes for its base maps, including historical maps, and also its ability to ingest spatial data directly from a desktop GIS. Downloading virtual globe files such as KML and KMZ for Google Earth and NMF files for ArcGIS Explorer that others have written, loading them into the virtual globe, and having students explore them would be appropriate once the student is familiar with the application and base data delivered with any of the virtual globe packages. It should be noted that educators should exercise some level of caution regarding the quality, accuracy, and validity of such data as noted above in the comments regarding metadata. After investigating the syntax of the source KML and NMF files, some may want to start creating their own KMLs and NMFs. Students could then use the

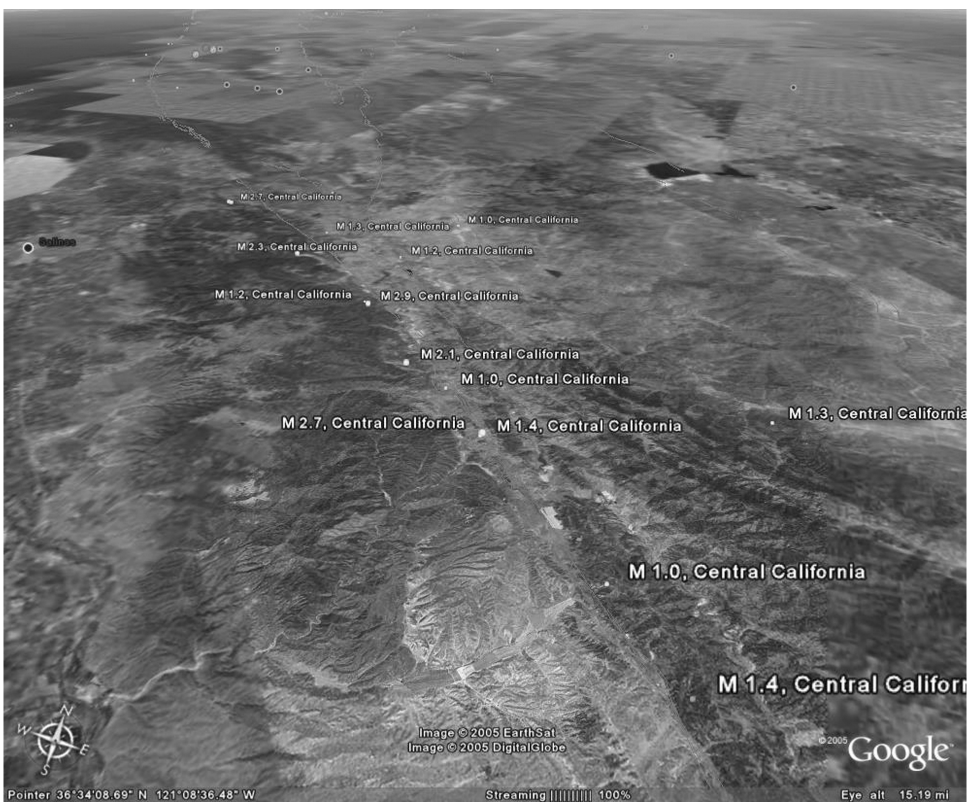

Figure 1. A portion of the San Andreas Fault in California with near-real-time earthquake data as recorded by the USGS, viewed in Google Earth. (Source: Google Earth.)

Figure 2. Marble Arch as seen from Google Earth with QuickBird satellite imagery from DigitalGlobe, Inc. (Source: Google Earth.)

instructor's generated files to go on a structured exploration of exactly what the instructor wanted them to examine, rather than just a random browse across the planet.

One interesting idea concerning the use of Google Earth is a tutorial on how to use it effectively in the classroom. From Quentin D'Souza's Teaching Hacks blog, *Google Earth 101* has emerged. This introductory course takes educators through the basics of using Google Earth's Free Version and looks at classroom integration ideas from K–12. There are hours of online videos for educators to familiarize themselves with the application, as well as different opportunities for educators to collaborate through topic-specific wikis, discussions, and potential synchronous chats. Feeds from topic-specific blogs, a large directory of Google Earth files and curriculum ideas, and resource wikis are just a few of the resources that can be found in this course. What makes this course different from other online courses is the ability to modify the course content and change the direction of the course through the use of topical wikis, discussions, and synchronous chats. Register for free at *http://www.teachinghacks.com/moodle/login/signup.php* and enroll in the course. One will need the enrollment key: googleearth101.

Virtual globe software and their applications are changing so rapidly that some of the information in this article may have changed by the time it is published. One excellent way to find out more about Google Earth and explore applications is to visit the Google Earth blog, at *http://www.gearthblog.com*. Next, access the growing library of Google Earth-based lessons at gelessons.com, or ArcGIS Explorer globes at *http://www.esri.com/arcgisexplorer* and NASA data on*http://worldwind.arc.nasa.gov/*.

As with any technology, however, the benefits of virtual globe tools are multiplied hundredfold in the hands of a teacher who can use the tool for inquiry-driven, active, problem-based, exploratory learning. Otherwise, students will likely be randomly flying around the Earth, learning about the location of places to be sure, but not engaging in the "whys of where" that form the core of geographic inquiry. A chief challenge in using these tools is the high level of interest that they create, and using that interest to nudge the student into thinking spatially about the Earth, its processes, and its issues.

Spatial Concepts and the Geography Standards

The infusion of the geography standards with the use of virtual globe software can help to increase geographic awareness and spatial thinking. The standards are built around three primary components: subject matter, by virtue of the eighteen content standards; skills, by virtue of five skill sets; and perspectives, in the form of the spatial and ecological perspectives, and the historical and economic supporting perspectives. Further, "geographic skills provide the necessary tools and techniques for students to think geographically" (National Academy of Sciences 2006).

Virtual globes can help students understand the world in virtual terms, and directly address the first three content standards (how to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective; how to use mental maps to organize information about people, places, and environments in a spatial context; and how to analyze the spatial organization of people, places, and environments on the Earth's surface) (National Academy of Sciences 2006). The interactive nature of virtual globes can facilitate learning through an enjoyable and individually-oriented session that allows students to explore the world and engage in research tailored to suit their individual interests.

The set of skills helps student to make an explicit link among three elements; virtual globes can help to reinforce and strengthen students' abilities to conduct scientific inquiry, engage in problem solving, and think spatially. Virtual globes can further facilitate learning through the

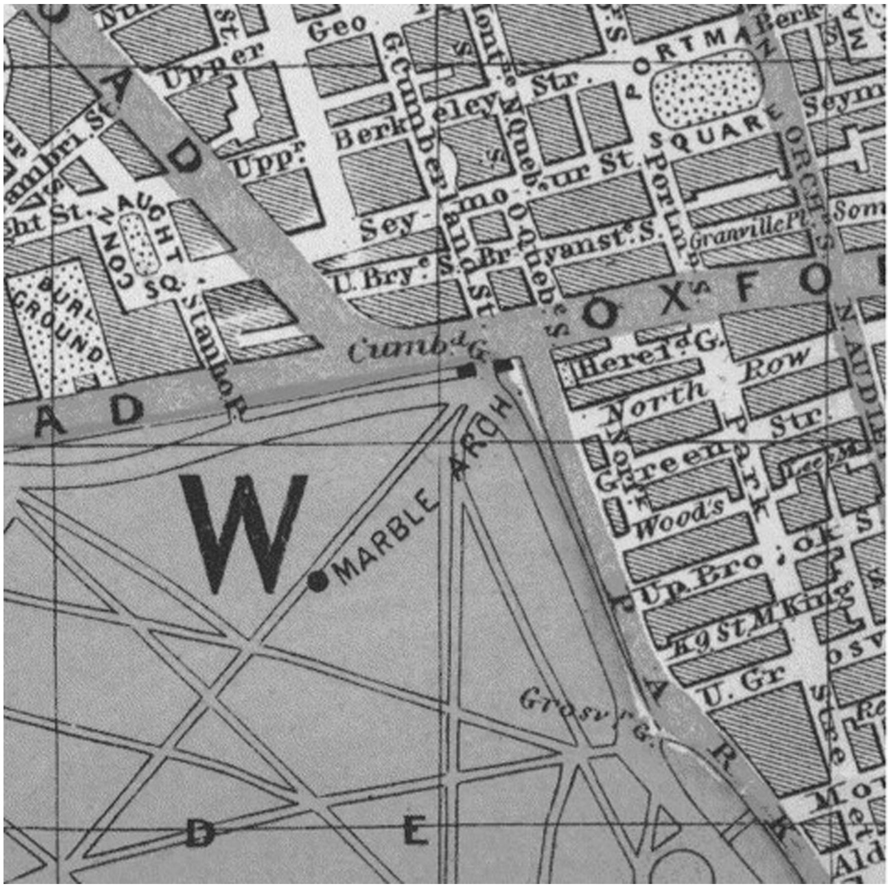

Figure 3. Historical map of Hyde Park with Marble Arch from the Victorian London activity. (Source: Reynolds Shilling *Coloured Map of London*, 1895.)

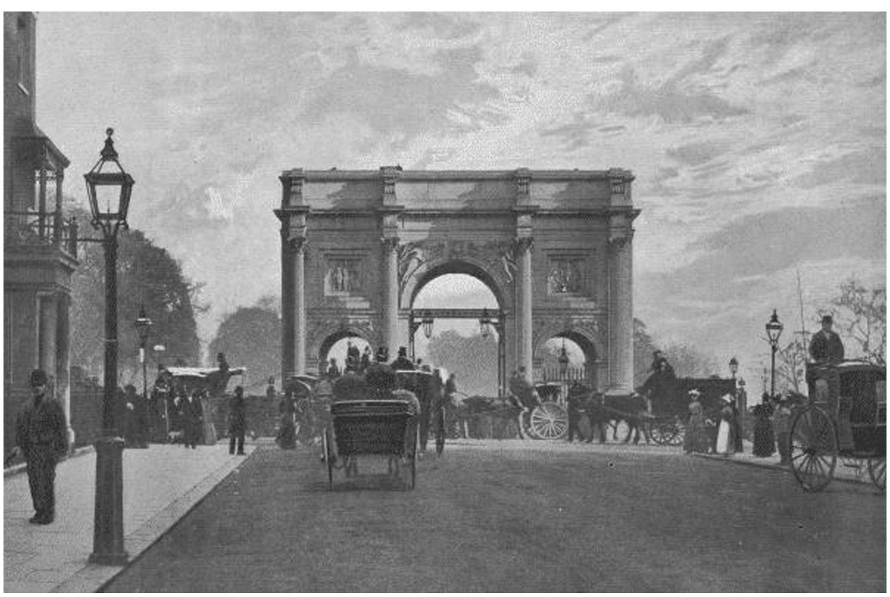

Figure 4. Historical photograph of Marble Arch from the Victorian London activity. (Source: *Dictionary of Victorian London.*)

five skills sets (asking geographic questions; acquiring geographic information; organizing geographic information; analyzing geographic information; and answering geographic questions) (National Academy of Sciences 2006).

Thus, virtual globes can help students meet the geographic standards in a more engaging manner. Virtual globes can help students meet expectations, as described in *Learning to Think Spatially* (National Academy of Sciences 2006), to have the ability at the end of the fourth grade to prepare maps and display basic geographic information, locate places and identify relationships between and among places, use basic measuring, and engage in spatial thinking, including analyzing the Earth's surface in terms of its spatial elements of points, lines, areas, and volumes. Having students more geographically literate earlier in life helps students understand the arrangement of objects in space, identify interrelationships among people and place, and apply geographic and spatial skills.

As described in *Learning to Think Spatially*, "The geography standards demonstrate the possibility and power of infusing spatial thinking into a discipline. They also show the need for a coordinated approach to spatial thinking standards across the curriculum" (National Academy of Sciences 2006). Perhaps virtual globe software, if learned by educators and successfully presented to students in an active setting, can fulfill the charge of the committee as they develop an understanding of the following questions:

1. What are the nature and character of spatial thinking?
2. How does the capacity for spatial thinking develop and how might it be fostered systematically by education and training?

Summary and Conclusions

Validity of Virtual Globes as Teaching Tools

Geography is an integrating discipline that helps students understand, participate in, and make informed decisions about the world around them. Some hardware and software costs, complexity of GIS tools, lack of GIS-based lessons, and other technological factors have slowed widespread adoption of GIS in the classroom. However,

the larger constraint has been an educational system that does not value spatial thinking and geography education, and the curricular fit of interdisciplinary spatial thinking. This issue is the same one that constrains the use of virtual globe tools. Yet virtual globes are an exciting and powerful mechanism to reinforce the connection people have with space and place and remove obstacles of classic GIS implementations in the classroom. The decrease in costs of hardware and software, better data availability, user-friendly graphical user interfaces, and the proliferation of the Internet that has significantly enhanced our interconnectedness across societies, have converged to allow geospatial information to be a driving force in educational enablement. The emergence of virtual globe software could be one of the most important visualization tools of our lifetimes. Will we, as geographers, champion its use as a powerful exploratory learning tool that supports numerous educational standards, enabling students to use spatial thinking skills in a practical manner?

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