

Developing an Evaluation Framework of Spatial Understanding through GIS Analysis of Volunteered Geographic Information (VGI)

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Abstract

This study integrates volunteered geographic information (VGI) into GIS and contextual analyses, and develops a framework to evaluate students' understanding of "locations and places in order to set national and international events within a geographical framework and to understand basic spatial relationships" as proposed by the Commission on Geographical Education (CGE). A web-based VGI was developed to allow students to share events taking place in the locations and places around the world. Three approaches are conducted to analyze all VGI records. First, GIS analysis shows the spatial pattern of VGI records and revealed students' mind map. Second, contextual analyses show students' preferences in certain geographic issues. Third, tag-cloud technology reflects students' spatial literacy based on the frequency of spatial-related terms. The results conclude that this study brings to the reader the exciting possibility of VGI and tag-cloud technology in allowing educators to evaluate students' spatial understanding and, ultimately, contributes to the future development of geography education.

Keywords: spatial understanding, volunteer geographic information, geography education, GIS

Introduction

One of the important objectives of learning geography is to develop students' knowledge and understanding of "locations and places in order to set national and international events within a geographical framework and to understand basic spatial relationships" (CGE 1992). To help people "use verbal, quantitative and symbolic data forms such as text, pictures, graphs tables, diagrams and maps to describe spatial phenomena and relationships" (CGE 1992), the design of the current curricula focuses on thematic geography and encourages students to be familiarized with their physical and human environment (Chang 2012). Meanwhile, various assessments are conducted

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to examine students' learning performances and inform instructional decisions (Wertheim and Edelson 2013). Among these modes of assessment, the design of marking systems is a traditional approach to evaluate students' knowledge of certain issues (Bednarz 2002). Furthermore, surveys and pre/post-tests are also prevalently used to highlight students' understanding of certain concepts (e.g., Huynh and Sharpe 2012; Lee and Bednarz 2009, 2011; Yin 2010). In addition to leaning the fundamentals of geography, it is essential to explore how individuals become aware of the space around people and the impacts on individuals' spatial understanding (Sui and Bednarz 1999; Bednarz and Bednarz 2004). Nonetheless, current assessments are designed for testing specific learning outcomes. While there is a need to present broad knowledge of space and place, it is hardly tested through the thematic treatment. Consequently, a new assessment without any subjective guidance should be developed to evaluate students' broad understanding of space.

Due to the innovation of computer technologies and the rapid growth of the Internet, web-based applications have played vital roles in allowing participation and sharing. The emergence of Web 2.0 is best described by the change from expert-centered information flow to a new way that collects information from collective intelligence and turning the web into a kind of global brain (O'Reilly 2007). The concept of Web 2.0 soon influences various research fields in general, and geography in particular. Inspired by the spirit of Web 2.0, for instance, Tuner (2006) coins the term Neogeography as a new branch of GIS. Goodchild (2007) proposes the concept of "Volunteered Geographic Information (VGI)" and emphasizes the importance of individuals in sharing geographical information and knowledge. Although some researchers criticize the credibility and accuracy of VGI (Tüzün et al. 2009; Gorman 2010), the user-generated context approach still plays a role in helping researchers explore users' awareness and comments of certain issues. For instance, Bartoschek and Keßler (2013) developed a web-based VGI platform and ask students to collect data for specific topics in geography classes. Their research shows that students benefit through the process of sharing VGI data, and implicitly show how they build up their domain knowledge. As a result, the use of participatory VGI applications will help teachers know what students know and what they are missing so teachers may determine which topics or issues they should emphasize.

It is also important to examine if students are capable to use their contextual knowledge and describe spatial relationships of certain events. Since writing offers a way to construct and preserve complex and abstract human thoughts (Sui and Bednarz 1999), it is essential to analyze spatial understanding through contexts associated with geography. Textual analysis has been adopted in evaluating learning performance and assessments of science literacy (e.g., Novak et al. 1984; Chang et al. 2001; Tseng et al. 2010). This approach adopts a text-mining technique that extracts participants' knowledge based on key terms they use to describe specific topics. The frequency of these terms is visualized as a concept map to reflect if participants understand certain issues by choosing the right terms. The evaluation has potential for assessment of geographical knowledge due to the nature of spatial representation on textual analyses and geographical locations that are aligned to the concept of spatial understanding. The

performance task can spatially represent students' knowledge of locations from the world map and evaluate if they have appropriately elaborated on the issue through the concept map generated from textual analyses.

As a result, this paper presents an elucidation on the central concepts of spatial understanding and develops an assessment through GIS and textual analyses of VGI records. To reach the goal, this research focuses on the integration of VGI to geography education, and in particular, how VGI benefits the assessments of students' spatial knowledge and ability of spatial learning. In the next section, the development of a web-based VGI system is introduced. Findings and analytical results will be discussed in Section 3. The advantage and usefulness of the combination of VGI and textual analyses will be concluded in Section 4.

Method

To examine students' prior knowledge of geography, 15 geography-major students were selected to participate in the three-week test (30 January 2012 – 17 February 2012). They are Year-3 university students and have taken fundamental courses broadly covering physical and human geography. A key concern of choosing these students was that due to the courses they have taken, they should have certain spatial understanding and are capable to write down their thinking with proper spatial terms. It will be intuitive to examine the degree of their spatial understanding and figure out to what extent they can elaborate space with their contextual knowledge.

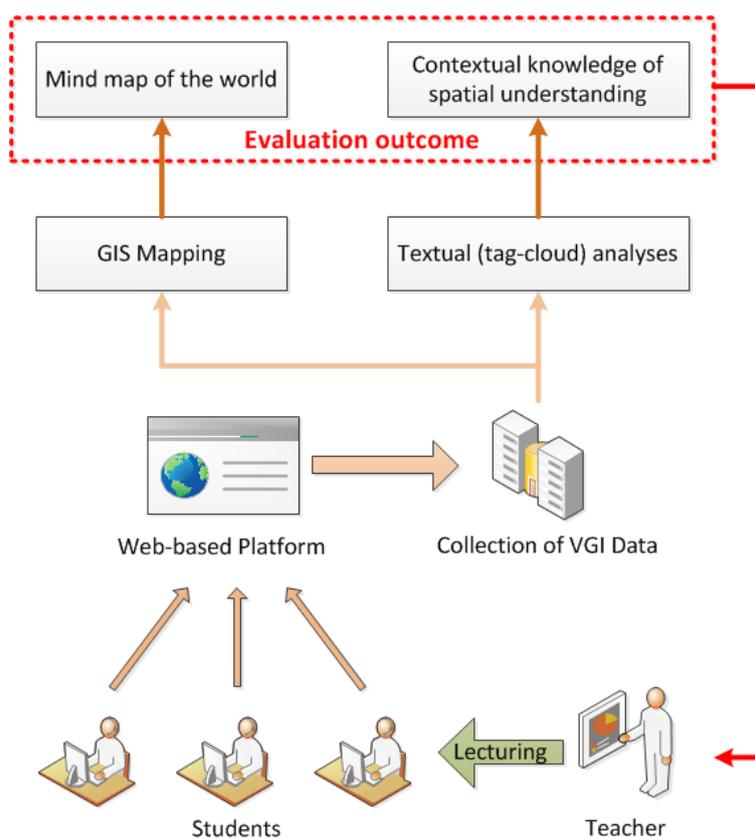


Figure 1.

The structure of the evaluation framework

The evaluation framework have three major components: a platform to let students write down their comments with certain spatial events, a collection of VGI data to examine students' prior knowledge, and a design of spatial and contextual analyses to explore students' spatial understanding (Figure 1). The three components are further elaborated as follows:

Development of Web-based Platform

The web platform is developed on Windows 2003 Server with Active Server Page (ASP) technologies. Map data is adopted from Google Map for rich spatial content and Javascript Application programming interfaces (APIs). Google Map APIs can be directly embedded in HTML files for recording VGI records from users. All records are stored in Microsoft SQL Server 2008 developer edition and can be loaded to webpages (Figure 2).

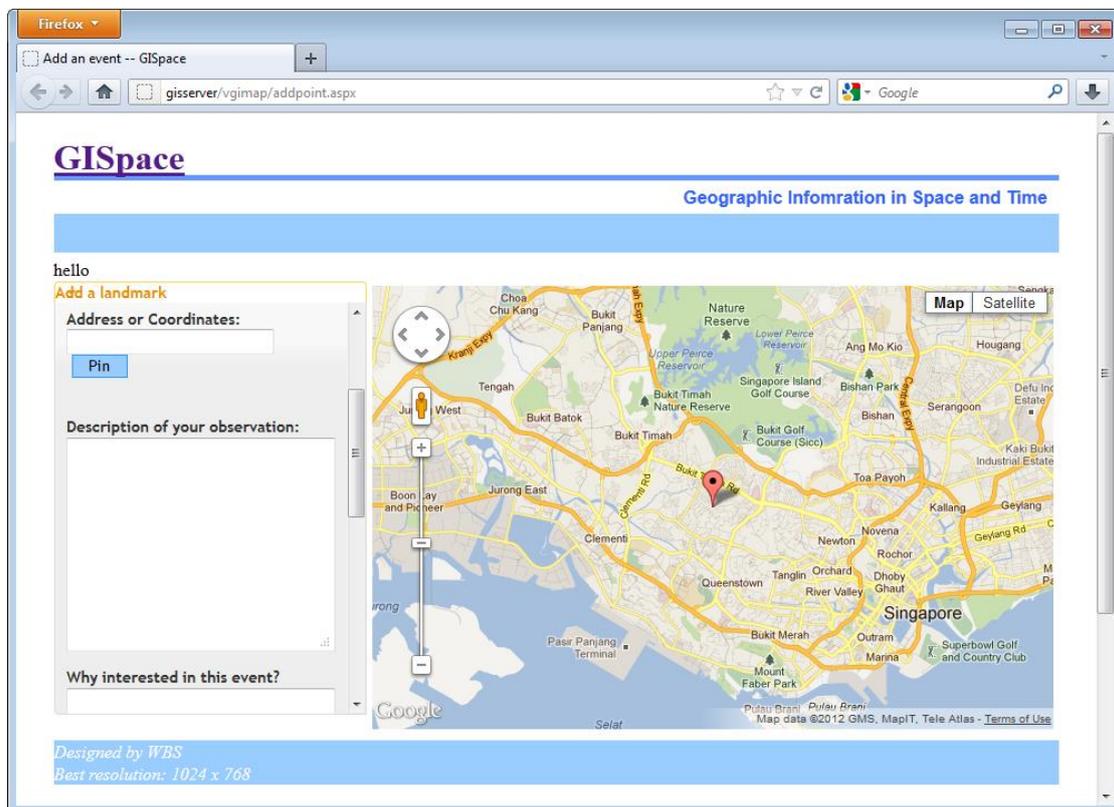


Figure 2.

Web-based GIS platform

Collection of VGI data

The design of data collection is to examine if students have any preferred knowledge of understanding specific areas of the world and if they are able to elaborate impacts of spatial events with their geography knowledge. Students are asked to pinpoint any

location of the world on the web-based platform and answer the following questions: 1) which spatial event do they observe, 2) why does that spatial event interests them, and 3) what is the influence of that spatial event on them? The rationale of this design is derived from Lee and Bednarz's (2009) research that examine how students develop spatial thinking. Textual analyses of VGI data will specifically focus on the following issues to estimate students' spatial understanding:

- How do students use their spatial knowledge to describe events that they are interested in?
- Do students choose words that contain spatial meanings to explain their findings?
- Why are students motivated by the events?
- Can students find any relationship between the events and the specific locations?
- How do students link what they have observed to their geography knowledge from school?

Consequently the collection of VGI data will be useful to capture and communicate knowledge in the form of a map for recognizing the world (Goodchild 2006; Bednarz and Kemp 2011) and get students' general knowledge of spatial understanding.

GIS Mapping of VGI data and Assessment of spatial knowledge

The collection of VGI data will be imported into ArcGIS for mapping and spatial classification. The outcome is generated as a thematic map to locate students' records and reflect students' choice of events and places in the world. The spatial pattern of the mind map can be intuitively used to show students' interests of the world and how teachers and media influence them. In addition, to further explore students' understanding of spatial literacy, VGI input will be analyzed based on spatial terms. The results will be presented as a "tag-cloud" map, which is a web technology to reveal words that are mostly used on a website by representing frequencies of words by varying the font size. The most frequently used words by the students will be highlighted with bigger font sizes, for example. The tag-cloud technology enables teachers to visually figure out terms that students use to describe spatial events. On the other hand, the assessment tool provides a self-directed learning process that helps students construct their spatial learning by understanding the use of spatial terms from their fellow classmates.

Findings

The VGI records disclosed some notable results. First of all, the spatial distribution of VGI records shown in Figure 3 revealed students' understanding and interests of the world. The mind map indicated that students were most interested and familiar with Asian countries, especially Singapore (Figure 4). Countries that drew students' attentions, including USA, UK and Australia, are developed economies that had influenced the history of Singapore. In addition, China and India had more VGI records than other Asian countries (except Singapore). An important factor was the increasing volume of international trade between these countries and Singapore since the late 1990.

Another reason is the influence of media because media tend to broadcast more information on these countries and get attention from the public.

Other than Asia and Western developed countries, there was no VGI record in South America. The only VGI records in Africa were related to football. Similar patterns could be found in Eastern Europe and Middle East. These areas were still under development and did not have consistently prominent influence in the students' conception of the whole world. These regions also had little connection to Singapore so that mainstream media would not pay much attention to them. When the social environment provided preferred information to the public, certain types of information were received by students and intuitively reflected onto their mind maps.

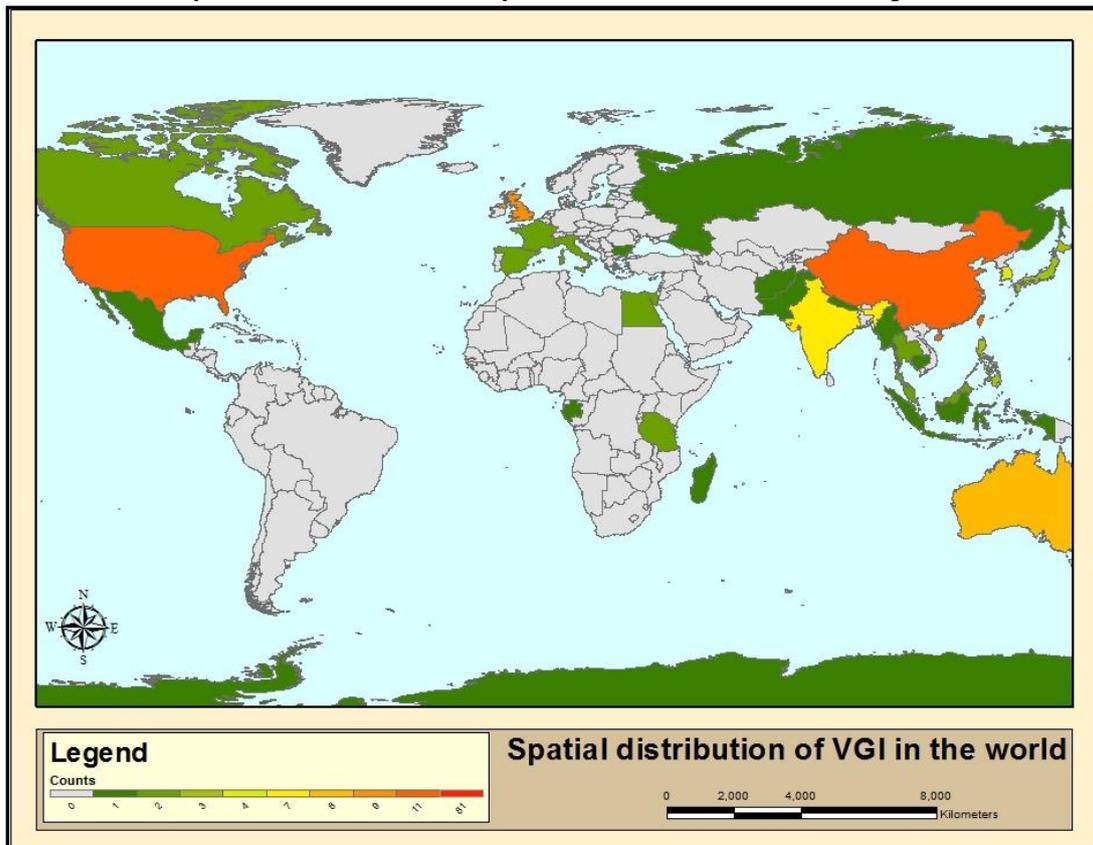


Figure 3.
Spatial distribution of VGI records

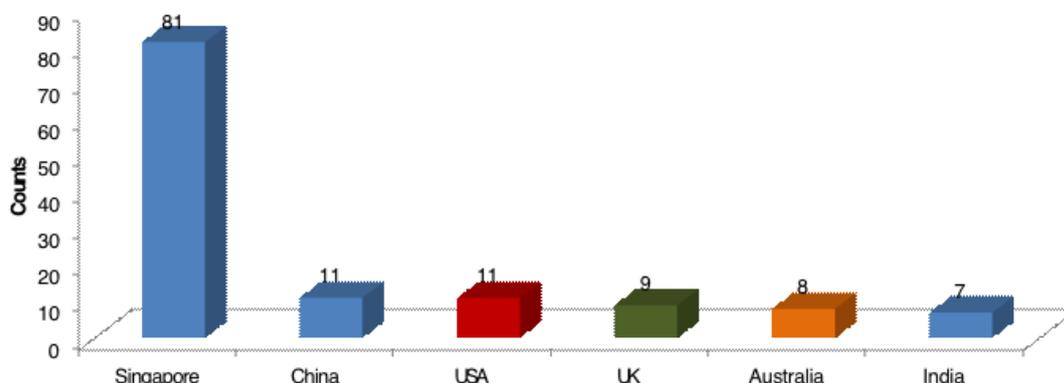


Figure 4.
Top countries with more than 5 VGI records

Secondly, the content of VGI records showed students had preferences and knowledge of certain geographic issues, but they had difficulties to elaborate well some spatial issues based on their observation and contextual knowledge. The records were divided into the following categories: 1) daily news, 2) transportation, and 3) environment issues. In the news category, students got information of different countries from media. However, the events were mostly politics, sports, crimes, science, and technology issues in developed countries. Due to the accessibility of media, it affected students' learning and understanding of the world. In addition, although reading news helped students learn the locations of cities or countries where events took place, lack of spatial context hardly made students think of any spatial relationship or influence. As a result, when students described their findings in this category, their answers for observation and influence were very vague and general without clear spatial meanings.

For transportation issues, it reflected a totally different pattern. Students had clear descriptions of their observations. They were also aware of the influences and impacts of transportation issues. They could even propose suggestions to avoid traffic congestion from spatial and temporal perspectives. The transportation issue significantly affects Singaporeans' daily life, so people and social media discussed about the issue frequently. Since students had personal experiences, they had better competence and more knowledge to examine the influences of this issue.

Some records specifically focused on environmental issues of the world, especially natural hazards, because events such as flooding or extreme weather took place during the period of this pilot test. Another factor was that students had learned or were learning environmental issues in class. They had knowledge to describe what they observed and were aware of the impacts of environmental issues. However, their reflections showed that students were only able to emphasize the importance of learning environmental issues, but not able to explain clearly how these issues affected the region or the world. It implied that students understood environmental issues but lack the ability to link their knowledge with the events. In addition, only two to three events were related to the local environment, and only one student recorded the events. It

seemed that if events covered by media and related sources were more likely to get students' attention. Otherwise students would not pay attention to observed changes in their living environment.

Thirdly, the analytical results of VGI records showed that students had constructed certain level of spatial literacy due to the use of spatial-related terms. To analyze if students properly adopted spatial-related terms to describe geographical issues, tag-cloud technology was introduced to conduct textual analysis. Tag-cloud technology visually summarized words that were frequently used and represented these words with bigger font sizes on a cloud map. Individuals could quickly uncover the essence of a text from the tag-cloud map. This intuitive approach of textual analysis could quickly reflect users' ideas throughout the text (Simon et al. 2010; Park et al. 2012). In this study, the content of VGI data analyzed by the tag-cloud method was shown in Figure 5. Spatial-related terms were categorized and shown in Table 1. The categorized results were filtered based on the frequency of terms. Terms that were neither noun nor spatial-related were not considered. In addition, if frequency of each term was less than 10 was also not considered because these terms were not significant enough for analysis. From Figure 5 and Table 1, "Singapore" was the word that was mostly mentioned. It matched results on the mind map that showed most events taking place in Singapore (Figure 4). Physical features, including natural and human-made features, were highly used in VGI records. Terms to describe concepts of space, direction, and topologies were not frequently adopted in students' responses. The results implied students were able to describe locations and geographical events related to transportation or environment issues by using related terms. They were also aware of the concepts of space since they used various terms, such as areas, countries, or world, to describe different scales of space and locations. However, they had difficulties in elaborating spatial relationship because terms related to spatial relationship or topologies were rarely used. In summary, through GIS and tag-cloud technologies, it was obvious that students had limited spatial understanding of the world, although their geographical knowledge and spatial literacy performed well in specific topics.

Table 1.

Frequency of spatial-related terms (counts ≥ 10)

a) Countries:

Singapore (118), Australia (16), Korea (16), China (10)

b) Natural features:

river (21), water (17), ice (15), land (11)

c) Human-made features:

road (46), school (26), park (17), university (16), cars (13), MRT (13), canal (10)

d) Concepts of space:

area (37), country (35), world (29), place (25), city (14), environment (10)

e) Direction and topology:

near (13), East (12), North (11), South (11), West (10)

(National Research Council 2010). Among the initiatives, professionally-oriented and technically-based geo-spatial technologies will play an important role in both geography research and education. Therefore, the development of new conceptual frameworks for these initiatives will be a key concern in the future of geography (Sui 2011). This evaluation framework integrates prevailing web-based development as the evaluation platform, which aims to help improve the development for educational purposes (Dragicevic 2004; Songer 2011) and the emergence of VGI, which is motivating in geography education (Bartoschek and Keßler 2013). It not only brings to the reader the exciting possibility of VGI and tag-cloud technologies in allowing educators to evaluate students' spatial understanding but also contributes to the future development of geography education.

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Biographical statements

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