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# Assessing Place Location Knowledge Using a Virtual Globe

Liangfeng Zhu, Xin Pan, and Gongcheng Gao

## ABSTRACT

Advances in the Google Earth virtual globe and the concomitant Keyhole Markup Language (KML) are providing educators with a convenient platform to cultivate and assess one's place location knowledge (PLK). This article presents a general framework and associated implementation methods for the online testing of PLK using Google Earth. The proposed framework and associated implementations can be easily exported to other applications that help assess geographic knowledge, engaging users with content from the physical environment and human systems at both local and global scales in a 3-D virtual-globe environment.

**Key Words:** 3-D visualization, cognitive mapping, geography education, Web-based learning, spatial knowledge

## INTRODUCTION

Geographic literacy, one of the thirty-four new literacy fields described by the United Nations in 1990 (Snively and Cooper 1997; Dikmenli 2014), is the competence of individuals to recognize geographic space, as well as the ability to understand, process, and utilize the basic skills of geography. It mainly involves knowledge of spatial locations of places, map reading skills, and understanding of human systems, society, and the physical environment associated with various regions (Backler and Stoltman 1986; Eve, Price, and Counts 1994; Winship 2004; Dikmenli 2014). Turner and Leydon (2012) believed that geographic literacy can be broken into two distinct but complementary components: geographic knowledge and geospatial recognition. Geographic knowledge refers to the ability to recall the names and attributes of different geographic locations at a variety of scales, while geospatial recognition refers to the ability to locate places and attributes on a map. Oigara (2006) noted that geographic literacy can be divided into three levels. Low-level geographic literacy consists of place-name and location knowledge. Middle-level geographic literacy involves the ability to understand the geographic interrelationships between human and physical environments in terms of cause-effect relationships. High-level geographic literacy is the capability of applying critical geographic knowledge to solve problems and make decisions in daily lives from a geographic perspective. While geographers may differ on what constitutes geographic literacy, many believe that place location knowledge (PLK), or the ability to locate and name places (such as countries, cities, landforms, and climate regions) on a map, is one of several components important to geographic literacy. Research on place-names and location knowledge considers that PLK provides the foundation upon which the study of geography is rooted (Torrens 2001). Although PLK cannot be fully equated to geographic literacy, Donovan (1993) asserted that PLK may be an essential indicator of geographic literacy, and it can partly reflect individuals' geographic literacy levels. Zirkle and Ellis (2010) believed that memory of place-names is foundational to deeper understandings of geography, and PLK is at least a point of departure on the long road to geographic literacy. Therefore, PLK is often regarded as a proxy or starting point for evaluating individuals' geographic literacy. Through assessing one's PLK, we can estimate his/her geographic knowledge and geospatial recognition ability.

In the last twenty years, an enormous amount of research has indicated a global decline in individuals' PLK. Whether schoolchildren or adults, their PLK is generally weak. For example, Torrens (2001) carried out a survey of more than 400 high school students in Dublin, Ireland. He found that the overall level of the basic location knowledge among those students was insufficient, and quite a number of participants in the survey could not locate European countries and major cities on a map. In a study whose purpose was to determine the geographic literacy levels of 1,077 first-year undergraduate students enrolled in Canadian universities, Sharpe (2005) found that those college freshmen only answered 53–64 percent of questions correctly. In another similar geographic literacy survey conducted with 510 young American adults aged between 18 and 24, National Geographic-Roper Public Affairs (2006) found that young Americans have a poor grasp of geography skills and knowledge of the world beyond United States' borders, with only about half (54%) of all questions answered correctly. Obviously, this low level of PLK provides a great challenge for people whose aim is to serve

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as responsible global citizens in a globalized society. In order to address this lack of PLK, it is an essential task to examine, evaluate, and improve the level of PLK among all sorts of people.

Recently, considerable attention from geographers and educators has been given to the cultivation of PLK among young people (Alkış 2006; Gençtürk 2009; Vajoczki 2009; Dunn 2011). A large number of research teams have launched a series of exploratory surveys on effectively determining individuals' PLK (Sharpe 2005; Dunn 2011). The majority of these surveys focus on using the questionnaire method that has been widely embraced by educators as a standard means to examine and assess one's PLK. In the questionnaire method, the participants are given a questionnaire involving a series of map questions accompanying several unmarked outline maps, and are required to identify features and fill in the names of some specified place locations on the maps (Torrens 2001; Turner and Leydon 2012). Depending on the answers to the questionnaire, the respondents' PLK can be assessed. Whereas the questionnaire method is flexible and easy to follow, there are still several serious limitations when using the existing questionnaire method to test one's PLK. One of the current main shortcomings of this method is that it requires a predefined questionnaire with fixed contents and number of map questions. Therefore, the questionnaire cannot be reused for the same person. Generally, a participant has only one opportunity to respond to a questionnaire. Thus this kind of testing could not achieve the desired goal of improving the participant's PLK during the administration of the test. More importantly, the questionnaire varies from one investigation to another, depending on the participants and the purpose of the study. Thus it is impossible to analyze the results of one survey in detail by cross-checking with other surveys.

Over the past two decades, the appearance of the Digital Earth concept and the development of associated implementation techniques, such as the Internet, virtual reality, geographic information system (GIS), global navigation satellite system (GNSS), remote sensing (RS), and other geospatial technologies (Qiu, Woller, and Briggs 2003; Butler 2006), provide an innovative opportunity for geographers and educators to cultivate and assess one's PLK. In the last ten years, several sophisticated and powerful online virtual globes, typified by Google Earth, have been developed and subsequently changed the way we interact with geospatial information (Butler 2006; Bailey and Chen 2011). As digital replicas of Earth, these virtual globes not only offer users the capability to explore and analyze worldwide landforms, geographic locations, and remote-sensing images, but also can be regarded as basic but reliable platforms for supporting location-based geoscience research and education (Patterson 2007; Schultz, Kerski, and Patterson 2008; Bailey, Whitmeyer, and De Paor 2012; Vogt and Hodza 2013; Whitmeyer and Patterson 2013; De Paor, Whitmeyer, Bentley, Burgin *et al.* 2014; Dordevic,

De Paor, and Whitmeyer 2014; Richards 2014). More recently, some research teams have invested considerable attention into how to improve one's geographic literacy by employing the existing virtual-globe platforms, especially Google Earth. With joint efforts contributed by geographers, educators, and virtual-globe developers, a series of techniques have been proposed and applied to address the needs of testing and improving individuals' PLK. For example, Thomas-Brown (2011) established an afterschool geography club to enhance students' geographic literacy in a relaxed, informal environment. With the aid of Google Earth and Google Maps, students in this club gathered each week to explore the world relevant to their lives outside of the school setting. Wallén (2013) designed a Web-based geographic discovery game (termed *GeoGuessr*) to help players to visit unacquainted locations in an immersive way. *GeoGuessr* drops players in randomly chosen locations on Google Street View, and requires them to guess their locations in the world using the visible clues. Inspired by *GeoGuessr*, two online geological challenges, *EarthQuiz* (De Paor, Whitmeyer, Bentley, and Dordevic 2014) and *Magical Geological Mystery Tour* (De Paor, Whitmeyer, and Dordevic 2014), were developed to present students with questions about sites around the world using Google Street View and Google Maps. In order to meet the pedagogical goal of the introductory-level geography course, Lee and Guertin (2012) designed an education game, termed *Penn State's Amazing Race*, to test and improve the place location knowledge of students in higher education. However, this game has serious limitations as it only provides several fixed locations for users to find according to an established order. Therefore, it could not be expanded to meet the actual requirements for testing the place location knowledge on global or other specified geographic locations.

The above-mentioned studies have shown that Google Earth provides us a novel technical means and a convenient supporting platform for the cultivation and assessment of PLK. For PLK testing, using the Google Earth virtual-globe platform has great advantages and added value. However, the current applications still fall short of systematic theories and standard workflow, and up to now there are still no readily available methods for freely testing one's PLK within arbitrary geographical areas. This limitation restricts the assessment and cultivation of geographic literacy using virtual globes. Therefore, it is an essential task to develop a universal framework for testing one's PLK within Google Earth.

In this article, we explore the techniques and associated implementation methods for the online testing of PLK using the Google Earth virtual-globe platform. Our ultimate goal is to present a general framework for online testing of PLK, which is suitable to deal with both local and global locations freely and flexibly. This framework not only can be used to measure the place location knowledge of the tested participants, but also can play a positive role to cultivate

and enhance the participants' geographic literacy through the testing process.

## GOOGLE EARTH AND ITS API

Google Earth, a free online digital globe released by Google Inc., gathers a large number of digital images, maps, and 3-D models together and drapes them over the solid Earth terrain model. By employing a variety of built-in visualization operations like rotating, panning, zooming, and swooping (tilting while zooming) anywhere over the globe, users of Google Earth can freely explore place-names, administrative boundaries, and other features from different perspectives in a dynamic and interactive manner.

Google Earth has become the most widely embraced virtual globe for geoscience educators and researchers (Bailey, Whitmeyer, and De Paor 2012), partly because it has an open architecture through supporting OpenGIS KML Encoding Standard (OGC KML) (Wilson 2008). As a universal standard for encoding digital geospatial information visually, KML not only offers us the capability to add custom geospatial data into Google Earth (or other virtual globes), but also allows us to interact with our own data through a variety of user interface controls (De Paor and Whitmeyer 2011). We just need to author a number of KML objects containing custom data in formats according to OpenGIS KML Encoding Standard, then Google Earth can load, visualize, and manipulate these KML objects automatically within its built-in 3-D/4-D visualization environment (Zhu, Wang, and Pan 2014). At present, Google Earth is becoming a reliable platform through which to integrate, visualize, share, and analyze geospatial information on both local and planetary scales.

Google Earth provides application developers with a great variety of powerful application programming interface (API) elements to open the access of its core functions (Google Inc. 2014). Using the Google Earth API, developers can embed the power of Google Earth into their Web pages for viewing in any browser that has the Google Earth plug-in installed. In order to create practical applications, developers can extend Google Earth's core functions by employing JavaScript code. In the Google Earth API, the various interfaces can be classified into two distinct types: browser plug-in-specific interfaces, or KML-based interfaces, depending on their naming conventions and purposes (Google Inc. 2014). Browser plug-in-specific interfaces are interfaces whose names begin with GE, allowing developers to gain access to core plug-in functionality and other miscellaneous options. They can be used to control the appearance of the Google Earth plug-in in a Web page, as well as load and display various map layers. KML-based interfaces are interfaces whose names begin with Kml, representing to deal with KML-related objects like `kml:Placemark` and `kml:LookAt`. They also can be utilized to realize the interaction between KML objects and users. More importantly, using the Google Earth API, developers

can add event listeners to the Google Earth plug-in to monitor some specific mouse events (such as click, mouse move, mouse over, etc.) for the purpose of customizing the user's interactive operation. With the efficient event-handling mechanism provided by the Google Earth API, it is convenient to build sophisticated Google Earth applications for controlling virtual-globe contents (Dordevic 2012; De Paor, Whitmeyer, Bentley, and Dordevic 2014; De Paor and Dordevic 2015).

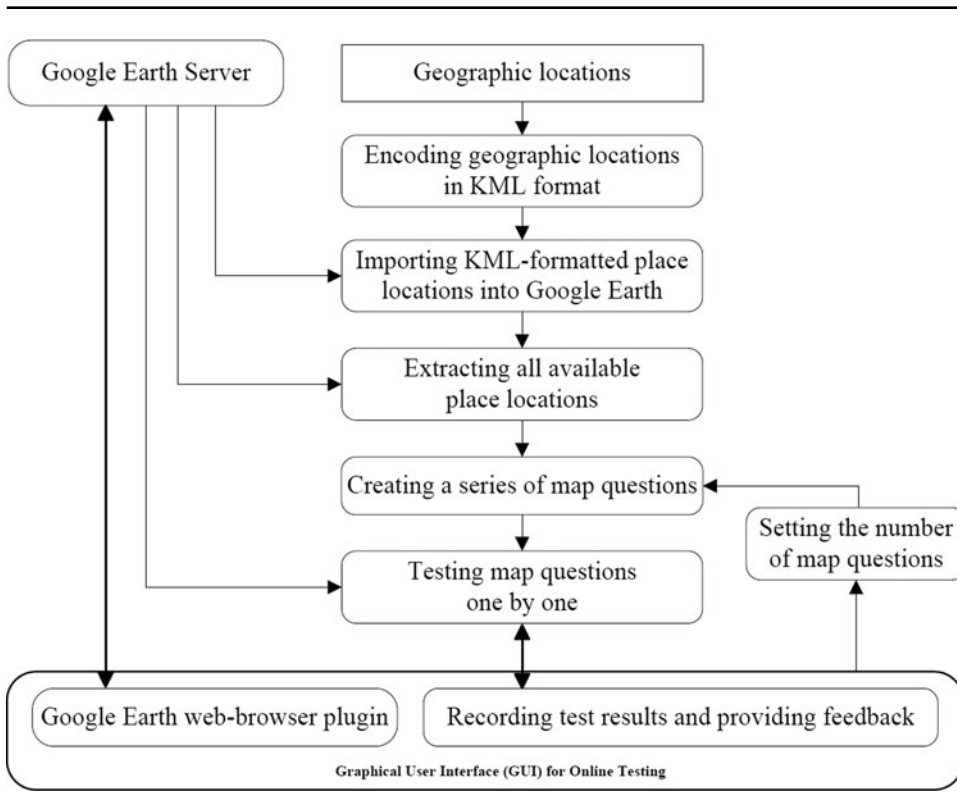
## GENERAL FRAMEWORK

Google Earth creates a computer-based, 3-D, mirror-world representation of geospatial information relevant to Earth's surface and near-surface (Bailey, Whitmeyer, and De Paor 2012). For the convenience of place locating, the Google Earth desktop application provides a sidebar with numerous built-in map layers, containing both administrative boundary information and label names for cities, states, countries, continents, oceans, and other place locations all over the world. Some but not all of these layers can be programmed in the Google Earth API. In the process of place location knowledge testing, we want to show only the boundaries of place locations without their label names because we want the participants to locate the places without any external assistance (Lee and Guertin 2012). However, as previously mentioned, in Google Earth the boundaries and the label names are merged into a built-in map layer that only can be turned on or off entirely. That is to say, they could not be separated and manipulated partially. Therefore, the Google Earth's built-in map layer is unable to meet the requirement of showing boundaries without labels.

To solve this problem, we need to turn off the built-in map layer in Google Earth, and provide a new map layer containing our own boundary information without labels. To achieve this goal, we should first describe and organize the boundary and name information for geographic locations to be tested according to the OpenGIS KML Encoding Standard. Then the KML-based place location information can be imported into the Google Earth plug-in for subsequent visualization, analysis, and online testing. According to this idea, we need to transition from the stand-alone Google Earth desktop application to the Google Earth Web-browser plug-in, and develop a simple but practical framework to support the online testing of place location knowledge within the Google Earth virtual-globe platform, including organizing and encoding geographic locations, as well as creating map questions, interactive testing, recording results, and providing feedback.

## KEY STEPS

Based on the recent developments and applications of place location knowledge testing, we present an implementing framework to support online testing of place location knowledge within Google Earth. The overall process for this



**Figure 1.** Overall framework for online testing of place location knowledge using the Google Earth virtual-globe platform. The sharp-cornered rectangles represent the data sets; the round-cornered rectangles represent the program components that process those data place location knowledge using the Google Earth virtual-globe platform; the thin arrows denote the data flows in the testing; and the double-headed arrows depict the graphical user interface controls and interaction between the program components and its user.

framework is presented in Figure 1. The implementation of the testing process can be decomposed into six key steps.

#### *Encoding Geographic Locations in KML Format*

The first step in the process is to encode geographic locations and store them for future use. According to the OpenGIS KML Encoding Standard, geographic locations can be encoded into KML placemarks without labels, and saved as KML strings or KML/KMZ files.

In virtual globes, geographic locations can be abstracted as KML geometry elements (like points, lines, polygons, and 3-D models) that can be draped over Earth's surface (Wernecke 2009). Therefore, we can employ the KML **Placemark** element to create a series of placemarks in order to customize names, coordinates, styles, and attributes of the geographic locations simultaneously. The spatial location of the placemarks can be defined by the KML **Point**, **LineString**, **Polygon**, **Model**, and/or **MultiGeometry** elements. For example, we can employ the **Polygon** element to represent the planar geographic locations like countries or other administrative regions. Since one country/region may consist of two or more polygons, we need to define a

**MultiGeometry** element, the container for multiple geometric primitives associated with the same KML feature, to collect those polygons.

#### *Importing KML-Formatted Place Locations into Google Earth*

The second step is to import the encoded geographic locations into the Google Earth plug-in, as the fundamental geographic data for the subsequent place location knowledge testing.

The Google Earth API provides three methods for importing KML objects into the Google Earth plug-in: *parseKml*, *fetchKml*, and *KmlNetworkLink* (Nurik 2009; Google Inc. 2014). Since the encoded place locations may be stored in KML strings or KML/KMZ files, we need to apply different methods to deal with those two different types of KML-formatted place locations: the *parseKml* method is ideally suited for importing place location information stored in KML strings, while the *fetchKml* or *KmlNetworkLink* method can be used to import place location information stored in KML/KMZ files.

#### *Extracting All Available Place Locations*

The third step is to extract all available place locations from the imported KML placemarks in the Google Earth plug-in, and construct a place-name list of all placemarks for subsequent testing.

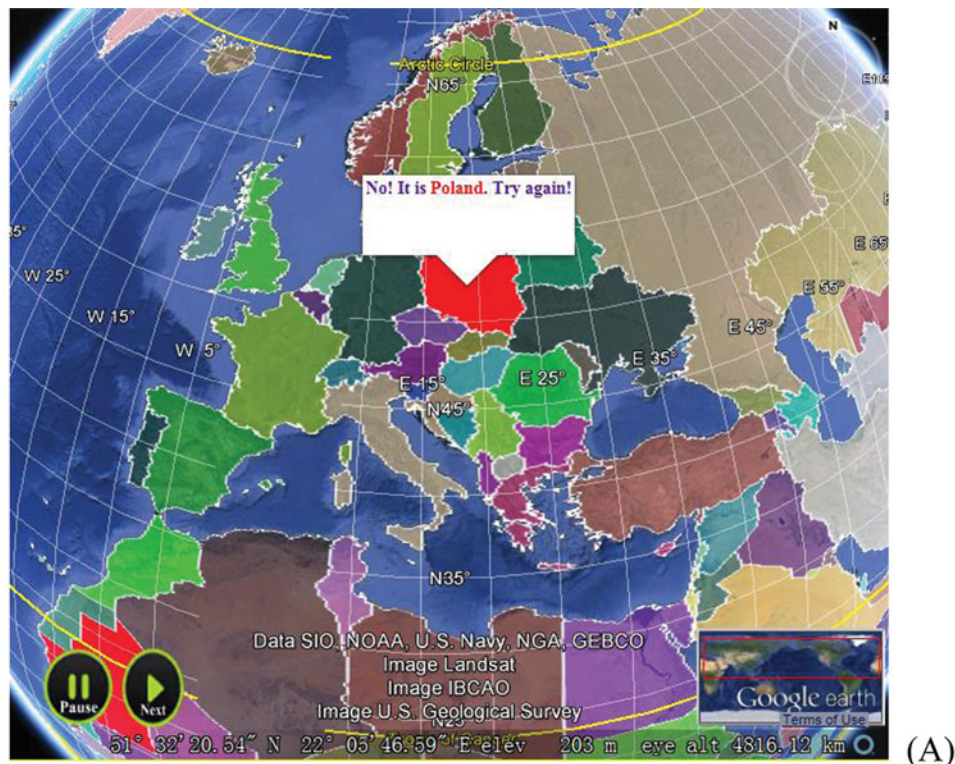
In order to extract place locations from the Google Earth plug-in, we first use the *getElementsByType* function in the Google Earth API to get a list of all available KML placemarks, then traverse the list and employ the *getName* method to obtain the name of each place location (Google Inc. 2014). Finally, we collect the names of individual place locations to construct a place-name list.

#### *Setting the Number of Map Questions and Creating a Series of Questions*

The main work in the fourth step consists of setting the number of map questions manually, and creating a series of map questions randomly.

In the process of place location knowledge testing, the optimum number of map questions varies greatly from individual to individual. On the one hand, having too many questions may become boring for beginners. But on





(A)



(B)

**Figure 2.** Feedback to the participant when he/she locates a placemark using the mouse: (A) If the participant navigates to a wrong location, he/she will receive a message balloon prompt stating that the placemark is not correct; (B) If the participant correctly locates the place, he/she will receive a message balloon for correct location. (Color figure available online.)

the other hand, too few questions may be insufficient to engage an experienced participant. To solve this problem, we need to give the participants a free hand to set the number of map questions. For example, we may provide a practical graphical user interface, like the input box or the selection box, to receive the participants' input of the number.

Once the number of map questions is confirmed, a stochastic process can be used for randomly selecting a number of place locations from the above-mentioned place-name list, and then we obtain a question list that can be used for the subsequent testing.

### Testing Map Questions One by One

In the fifth step, participants conduct the online testing interactively. Based on the question list generated by the previous step, each question is submitted to the participants one by one, and requires the participants' responses.

In the testing process, we successively present the place-name for the participant to find. Using the mouse, the participant navigates around the Google Earth virtual globe to find the correct place location matching the given name. By employing the *addEventListener* function provided by the Google Earth API (Google Inc. 2014), we continuously monitor the interaction between the participant and the KML placemarks. When the participant locates a placemark utilizing the mouse, the Google Earth plug-in extracts the name of the placemark and compares it with the presented place-name automatically. If the two names do not match, it means the participant navigated to a wrong location. The participant will receive a message balloon prompt stating that the placemark is not correct, and then he/she continues to locate other placemarks until finding the correct one (Fig. 2A).



Figure 3. User interface of GeoQuiz. (Color figure available online.)

If the two names match, it indicates the participant correctly located the place. The participant will receive a message balloon prompt indicating that he/she has found the correct location (Fig. 2B), and then he/she proceeds to the next question immediately.

During the process of searching and locating geographic locations on the Google Earth virtual globe, there is a pressing need to highlight the targeted location when the mouse is placed over a specified placemark. In order to achieve this effect, we first employ the *addEventListener* function to create two event listeners that monitor the mouse-over and mouse-out events respectively (Google Inc. 2014). Since these two event listeners listen for mouse events consecutively, they can be used as the triggers for controlling the start and the termination of the highlighting effect.

#### Recording Test Results and Providing Feedback

During the testing process, the total scores of the participants, as well as answer results and elapsed times spend on individual questions, are recorded and presented in a scoreboard automatically. Using the scoreboard, the participants can conveniently determine the test results and their current progress in real time. Furthermore, we can provide a number of standardized questions for the participants, and create a high-score table to encourage them to play more than once. In the high-score table, the scores are weighted by the length of time it takes for the participant to answer each question. At the end of the

testing, we can evaluate the place location knowledge levels of the participants according to the final scores.

## A PRACTICAL EXAMPLE

### User Interface

To illustrate the feasibility and practicability of the proposed framework for online testing of place location knowledge, a Web application, termed *GeoQuiz*,<sup>1</sup> was developed using the Google Earth plug-in and its JavaScript API. *GeoQuiz* is designed for the purpose of examining and improving one's place location knowledge of countries around the globe. As shown in Figure 3, the user interface of *GeoQuiz* is composed of three parts: (1) the instruction area, which is designed for displaying rules of the test, is located at the top of the Web page; (2) the Google Earth container, incorporating two screen-overlay-based custom buttons (one is the Start/Pause button and the other is the Next button), is located at the left side of the screen; and (3) the testing information area, which is used to set the number of map questions manually, present map questions in an orderly sequence, and collect test results sequentially, is located at the right side of the screen. When a user opens the *GeoQuiz* Web page, an embedded Google Earth window appears, loading and displaying the world's countries gradually. The encoded global country locations, containing boundary information without any label names, are represented as KML polygon placemarks and draped over the surface of the Google Earth virtual globe. *GeoQuiz* extracts all available place locations from the KML polygon placemarks, and automatically creates a selection of map questions for the participant to take the test.

When using *GeoQuiz*, the participant first sets the number of map questions through a drop-down list box, and then clicks the Start button embedded in the Google Earth container to start the testing. According to the place-name presented in the testing information area, the participant navigates the virtual globe to find the correct country matching the presented name. When navigating to a target place, he/she clicks the place to determine whether the selected place matches the presented name, and a message balloon will appear on the screen to feed back the test result to the participant (Fig. 4). During the testing process, the test results of individual questions are recorded in the scoreboard synchronously. If the participant successfully finds a place location in the allotted time, the place-name will



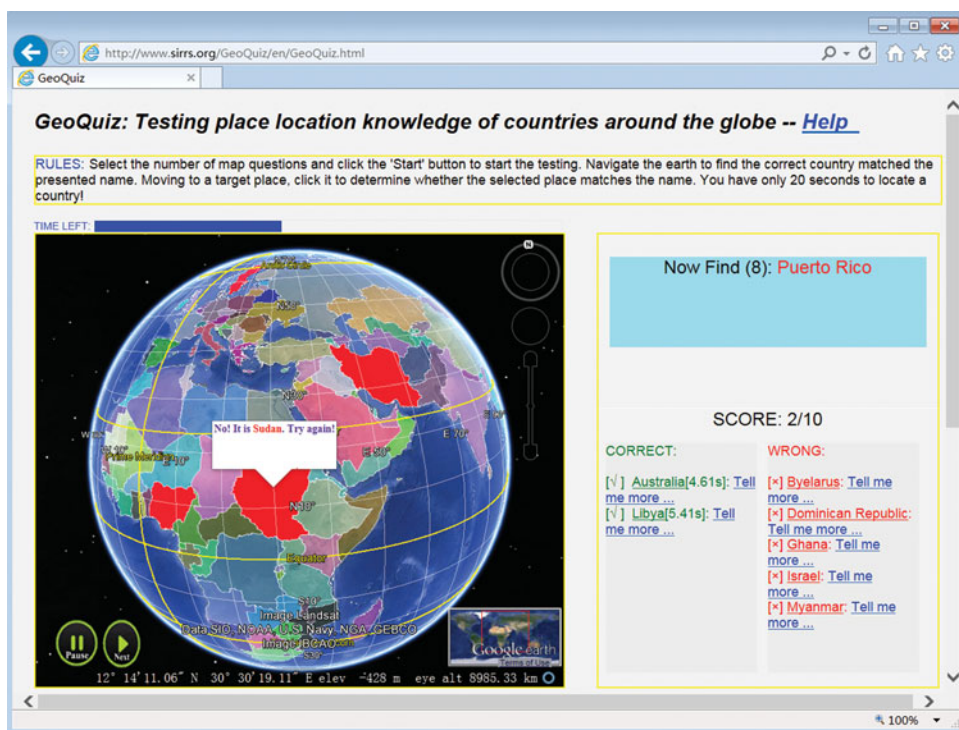


Figure 4. Online testing of place location knowledge on world's countries using GeoQuiz. (Color figure available online.)

appear in green coloring in a results column on the left side of the scoreboard; otherwise it will appear in red coloring in a results column on the right side of the scoreboard. Each of these place-names has *Tell me more...* hot links to Wikipedia pages for the places. After completing a round of testing, the participant can reset the number of map questions and launch a new round of testing. At the end of the test, the participant can click the place-names in the scoreboard, and the Google Earth window would fly to the correct place to reinforce the learning.

In order to increase attention and competitiveness, we embed a timer into the *GeoQuiz* Web page for keeping track of how much time participants spend on each question. The timer gives the participant twenty seconds to find each place. If the participant exceeds the allotted time, it can be assumed that he/she could not correctly locate the presented place on the Google Earth virtual globe, and *GeoQuiz* will jump into the next question to continue the testing.

### Use of GeoQuiz

The main potential user communities of *GeoQuiz* are geography educators and their students. The structure of *GeoQuiz* is ideal for engaging students in assessing and improving their knowledge of global locations. In September 2014 we released the first version of *GeoQuiz* and conducted an initial testing in the geography department of East China Normal University. More than 150 first-year

undergraduate geography students accessed the *GeoQuiz* Web page to do a self-assessment of their PLK at the beginning of an introductory-level geography course.

From the feedback we have gathered, most of the students felt comfortable with the user interface of *GeoQuiz*. They did not encounter many difficulties because they were familiar with the use of the Google Earth virtual globe. After completing the testing, 95 percent of the participants indicated their belief that *GeoQuiz* was an instrumental tool in improving their PLK. Some students even hoped to be able to incorporate several game elements (like real-time competing between multiple participants) into the next version of *GeoQuiz* to increase the competitiveness.

### CONCLUSIONS

Google Earth is an instrument for promoting geoscience education and research. It provides educators a convenient

platform to cultivate and assess their students' place location knowledge. Compared with the previous techniques, the substantial advantages and benefits of using the Google Earth virtual-globe platform are obvious:

1. Google Earth offers a unified and standardized platform for conducting place location knowledge testing.
2. The visual representation of the Earth is helpful to develop students' ability for locating and naming places on the Earth from a spatial thinking perspective.
3. Google Earth possesses a simple but flexible architecture through which to easily conduct customizable developments without additional costs. According to the actual requirements of place location knowledge testing, educational developers can encode their own geographic locations in accordance with the OpenGIS KML Encoding Standard, and employ the Google Earth plug-in and its JavaScript API to expand the functionality of the existing Google Earth desktop application. In this way, educators can build complicated applications for the online testing of place location knowledge.

In this article, we have developed and illustrated the general framework and associated implementation methods for the online testing of place location knowledge using Google Earth. *GeoQuiz*, an implementation program



focusing on testing one's place location knowledge of countries around the globe, is presented to illustrate the effectiveness of the proposed framework. The most significant feature of the proposed online testing framework and associated implementation program is that they have strong flexibility. Therefore, they can be easily exported to other applications that help assess geographic knowledge from the physical environment to human systems on both local and global scales in a 3-D virtual-globe environment.

It should be pointed out that the implementation program, *GeoQuiz*, relies heavily on the Google Earth plug-in and its JavaScript API (the Google Earth API). In December 2014 Google decided to turn off the Google Earth API in December 2015 for security reasons (Hoetmer 2014). However, it is likely that Google will release a new Web-enabled version of Google Earth by that time. We will continue to maintain and improve *GeoQuiz* when Google shares the latest Google Earth for the Web platform. In the future, we will rewrite the computer code of *GeoQuiz* and add more game elements into it based on the feedback of the participants.

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#### NOTE

1. Computer code of *GeoQuiz*, including source code and instruction guide, can be downloaded from <http://www.sirrs.org/GeoQuiz/code/GeoQuiz.zip>. For testing one's place location knowledge of countries around the globe, we refer the reader to the Web site at <http://www.sirrs.org/GeoQuiz/en/GeoQuiz.html>. Any computer that already has the Google Earth plug-in installed can freely access this Web page.

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