

DEVELOPING AN INTERACTIVE APPLICATION EMBODIED IN THE GEOSCIENCES EDUCATIONAL PROCEDURE

Tsangaratos P.¹, Perraki M.¹ and Ilia I.¹

¹ National Technical University of Athens, School of Mining and Metallurgical Engineering,
Department of Geology, ptsag@metal.ntua.gr, maria@metal.ntua.gr, gilia@metal.ntua.gr

Abstract

The aim of this study is to develop a Geovisual Mineralogical Cognitive Tool (GeMiCo Tool), a digital application that utilizes techniques from the domain of Information and Communication Technology. The application is part of the educational tools used at the Mineralogical Museum of the School of Mining and Metallurgical Engineering, National Technical University of Athens and concerns students of Higher, Primary and Secondary Education. The learning tool developed here embodies Google Earth API (Application Programming Interface), allowing users to interactively display and investigate geological and mineralogical related data. By that, users are able to select and present thematic layers of information related to the geo-exhibits, to create queries and searches and to navigate in 3D environment. The application runs on a large format multi-touch interactive display in the Mineralogical Museum of NTUA that attracts audiences and engages them in interactive collaborative tasks.

Key words: Virtual Globe, Google Earth API, GeMiCo.

Περίληψη

Σκοπός της παρούσας μελέτης είναι η παρουσίαση ενός Γεω-οπτικού Ορυκτολογικού Γνωστικού Εργαλείου (GeMiCo Tool), μια ψηφιακή εφαρμογή που χρησιμοποιεί τεχνικές από τον τομέα της Τεχνολογίας των Πληροφοριών και Επικοινωνιών. Η εφαρμογή αποτελεί τμήμα των εκπαιδευτικών εργαλείων που χρησιμοποιούνται στο Ορυκτολογικό Μουσείο “γαιο-ΟΡΑΜΑ” της Σχολής Μηχανικών Μεταλλείων-Μεταλλουργών του Εθνικού Μετσόβιου Πολυτεχνείου και αφορά σε φοιτητές ΑΕΙ καθώς και μαθητές πρωτοβάθμιας και δευτεροβάθμιας εκπαίδευσης. Η εφαρμογή ενσωματώνει το Google Earth API, που επιτρέπει στους χρήστες να διερευνούν και να επεξεργάζονται με διαδραστικό τρόπο γεωλογικά και ορυκτολογικά δεδομένα. Οι χρήστες έχουν τη δυνατότητα να επιλέγουν θεματικά επίπεδα πληροφοριών που σχετίζονται με τα γεω-εκθέματα, να δημιουργούν ερωτήσεις και αναζητήσεις και να πλοηγούνται σε 3D περιβάλλον. Η εφαρμογή είναι εγκαταστημένη σε μια μεγάλου μεγέθους διαδραστική οθόνη (τεχνολογία multi-touch) η οποία προσελκύει το κοινό να συμμετάσχει σε διαδραστικές ατομικές και ομαδικές εργασίες.

Λέξεις κλειδιά: Virtual Globe, Google Earth API, GeMiCo.

1. Introduction

The technological enhancement that has been recorded during the last two decades in the Information and Communication Technology domain has changed the way societies appreciate and embrace technology. Technology is becoming the essential component in each of our everyday activities. It's everywhere, in the way we store, recall and report data, in the way we communicate, we travel, we learn. Educational procedures and scientific research practice are primary influenced from such a development. Specifically, web-based information and knowledge systems have revolutionized the traditional lecture-based educational approaches. Currently, there are several education and research initiatives that aim to effectively utilize these technological advances and address the challenges that accompany those by producing powerful educational tools, which could assist in a positive way during the learning process (Manduca & Mogk, 2002, Atkins et al., 2003, Brindisi et al., 2006). According to Blumenfeld et al. (1991), this kind of resource can make difficult or unseen material more accessible, more understandable, and interesting or motivating to students.

The objective of the present paper is to describe such an educational resource addressed for students of Higher Education, the Geo-visual Mineralogical Cognitive (GeMiCo) tool. The tool takes advantage of the power of visualization since it embodies Google Earth's Application Programming Interface (API). The main educational goals of GeMiCo was to allow students to interactively display and investigate geological and mineralogical data on a Virtual Globe and by this support the teaching of geography and geology. Virtual Globes (VG) is similar to desk globes; however they have the additional capability of simultaneously represent many different thematic layers of information. They are capable in showing spatial data and information at multiple scales and in multiple ways, including text, photos, animation, voice recordings and videos (Butler, 2006). The tool is developed as a web-based tool, designed and compiled with Visual Basic 6.0, a third-generation event-driven programming language and integrated development environment (IDE). The application runs on a large format multi-touch interactive horizontal display in the Mineralogical Museum "γαλο-ORAMA" of National Technical University of Athens, which furthermore promotes collaboration among students as it allows small groups of students to gather around the display and become more active participants.

2. Materials and Methods

2.1. Virtual Globes Technology

The core stone of GeMiCo tool is the VG interface. The interface allows data and information that is related to geological and mineralogical concepts to be visualized having a spatial context. The idea that computers could be used to model a Virtual Earth or Globe is as old as the Internet itself. Buckminster Fuller's 1962 concept of a Geoscope and MIT's Aspen Movie Map multimedia project in the 1970s, were both forerunners for the actual development of an interactive, computer-based model of the entire planet (Bailey & Chen, 2011). According to Rakshit & Himmelberger (2008), the advent of VG and online mapping applications, has generated an enormous interest in spatial representations of data among many non-geographic communities, such as educators and researchers, who had previously, very little to no expertise, in geospatial technologies.

VGs are presented as 3D software models, which are capable of modelling the Earth or other environments of the universe, like Moon, Venus and Jupiter. Their main characteristic is the ability to freely move around by changing the viewing angle and position. They allow the representation of different layers of information on the surface of the Earth that may have spatial or non - spatial attributes. VGs are capable of displaying, man - made features such as infrastructure networks and buildings, elevation data or representations of demographic quantities. They can handle spatial data such as geodatabases, shapefiles, KML/KMZ, GPX and raster formats (JPEG, GeoTIFF,

MrSID) and integrate a wide variety of context such as photos, videos, documents, 3D models placing them in a geographic content (De Paor et al., 2008, Tsangaratos, 2011).

There are more than 30 VG available on the Internet but the most popular ones are: Google Earth, NASA World Wind, Marble and ArcGIS Explorer, due to the availability of the data they provide, the ease of use and the advanced functionalities that they include. As already mentioned above, the educational tool developed here embodies a VG and specifically Google Earth's API. The Google Earth API is a free beta service, available for any web site or web-based application. The Plug-in and its JavaScript API allow users to place a version of Google Earth into web pages or web-based applications. The Google Earth API can display placemarks, lines, polygons, overlays and 3D models on the imagery, just as the standalone version of Google Earth can. The plug-in supports several of the Google Earth layers of information, including terrain data, infrastructure network, borders and buildings (Brown, 2006, Tsangaratos, 2011). The Google Earth API as well as Google Earth, uses aerial photos and QuickBird satellite images (less than 1 m resolution) for some areas, Landsat imagery for other areas and Shuttle Radar Topography Mission (SRTM) elevation data for terrain visualization. Since the data come from different sources and the coverage is not uniform, some areas of the globe appear crisp all the way down to street level, whereas other areas are blurry from a great distance. In Google Earth API and Google Earth, no imagery is viewed in real time. According to Google, all of the available terrain and imagery information are less than 3 years old and are continuously updated. The internal coordinate system of Google Earth API and Google Earth is geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 datum. Google Earth API and Google Earth, adopts Keyhole Markup Language (KML) for expressing geographic annotation and visualization. KML is used as the format for describing, organizing and visualizing geographical objects (Wilson et al., 2008). It represents a hierarchical data system where the geographical objects can be populated in a nested tree structure (Wernecke, 2009).

3. Geo-visual Mineralogical Cognitive Tool (GeMiCo)

3.1. General Information

Geo-visual Mineralogical Cognitive (GeMiCo) Tool is a web-based learning tool that takes advantage of the power of visualization. Specifically, the learning tool developed here embodies Google Earth API, allowing students to interactively display and investigate geological and mineralogical data. The GeMiCo tool runs on a large format multi-touch interactive display in the Mineralogical Museum “γαιο-ORAMA” of the School of Mining and Metallurgical Engineering of National Technical University of Athens, Greece (<http://www.metal.ntua.gr/index.pl/museum>). “γαιο-ORAMA” has a rich mineral collection containing specimens mainly from Greece but also from all over the world, exhibited in a recently (2010) built modern two-floor building of approximately 300 m². It is equipped, among others, with interactive multimedia and a set of relative tools and activities, such as the GeMiCo tool, are developed.

Figure 1 shows a screenshot of the tool that presents data and useful information about the area of Lavreotiki (Janikian, 2009). The GeMiCo Tool incorporates advanced information technology, research-quality data sets, and supportive materials in order to facilitate effective inquiry-based science education at all levels. Geological and mineralogical information is often difficult to assimilate by students, since it involves three to four dimensional processes taking place in macro-, micro- and nano- scales. In many cases the students are not able to explore and record large scale geological phenomena in actual conditions. In these cases, research-quality data sets can replace student-collected data, and computer technology can be used to represent the data visually in a friendly-to-use manner.

The GeMiCo Tool is a set of Internet accessible tool that provides much of the functionality of commercial GIS software at no cost. By storing the data in a web environment instead of providing it on CD-ROM or DVD, the tool provides students access to a much larger database. This also

allows the developers to easily update the data sets and system tools without the time consuming and costly process of redistributing them to the end-users.

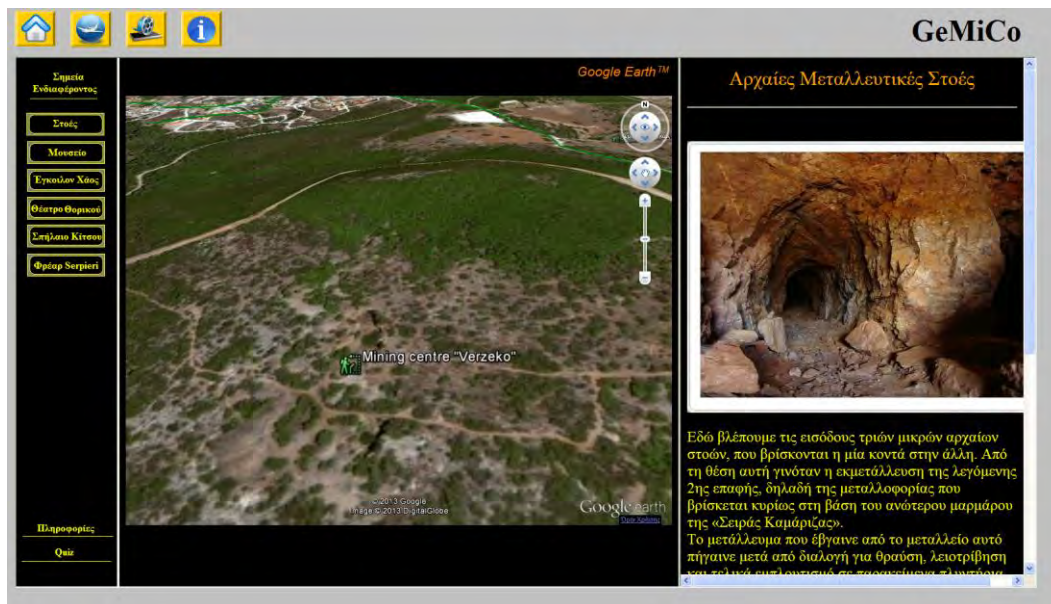


Figure 1 – Geo – visual Mineralogical Cognitive Tool (GeMiCo).

3.2. System Architecture

GeMiCo Tool was designed and compiled using Visual Basic programming language. The main frame consists of a single form, with a split control panel oriented vertically. The left part contains the controls that are used to navigate and explore the available data. The right panel contains a WebBrowser Object, docked into it, specifically a HTML Document. In the case presented, the HTML Document was the Google Earth API. The Google Earth API is a JavaScript library that allows developers to add Earth plug-in objects to their sites. The API also provides programmatic access to the plug-in objects and the features inside of them. Web site developers can use the API to facilitate interaction between standard HTML elements and Earth plug-in instances. A simple javascript code that enables the Google Earth API on a dynamic HTML page and uploads a KML file is shown in Figure 2.

Events that occur in the Google Earth API which is contained in the WebBrowser Object are captured and forwarded to a procedure in the left panel of the main frame. A Visual Basic script, which is embodied in the form's source code, executes specific functions in response to the forwarded events. The same procedure is executed with events and scripts performed in the main frame and forwarded to Google Earth API HTML Object.

The GeMiCo Tool is comprised of three main components:

- Educational web pages designed as user guides and information database.
- An interactive mapping tool, Virtual Globe Frame.
- A set of multiple-choice quizzes and tests designed to perform interactive learning procedures.

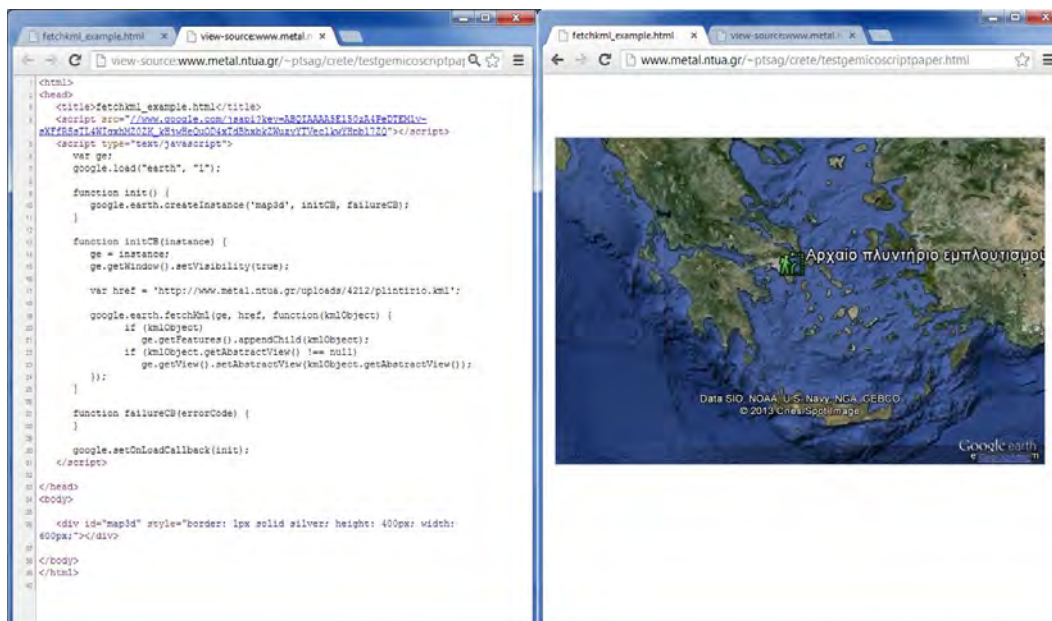


Figure 2 – Javascript Code in HTML.

3.2.1. Educational web pages

The educational web pages embodied in GeMiCo Tool, allow students to work with actual data sets acquired by researchers and provide the ability to manipulate, query and display in their own way the available data. Thus, students are driven by their own curiosity and get more involved in the learning process. The architecture of GeMiCo Tool provides students with the tools to learn about geological processes and mineral formation and occurrence through inquiry and discovery (Figure 3).

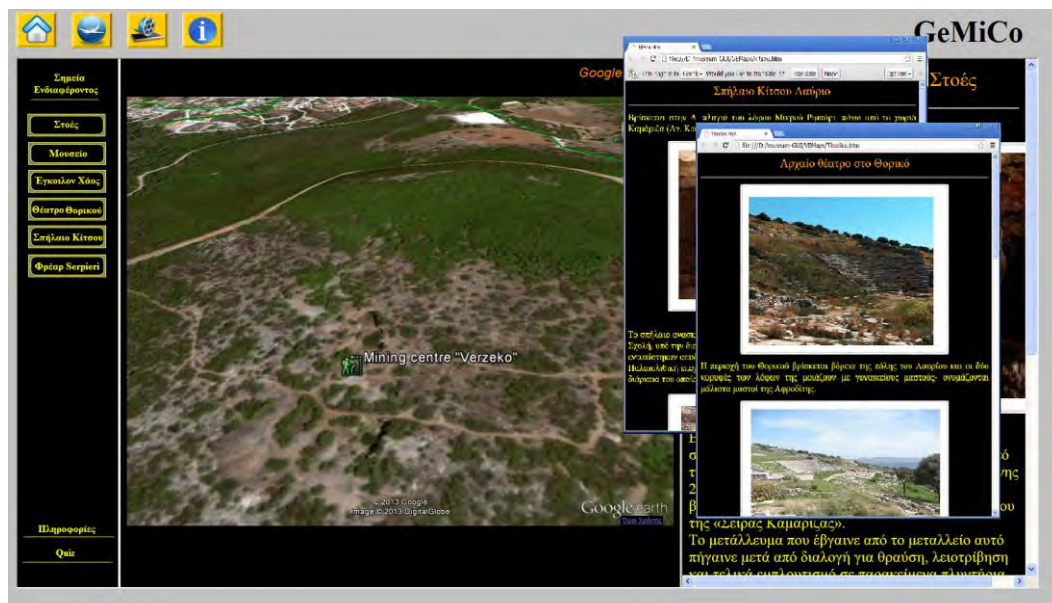


Figure 3 – Educational Web pages.

The web pages are primarily comprised of text and images presented in hypertext markup language (HTML) format. Their main scope is to illustrate information and knowledge concerning geology and mineralogy and to cover topics such as geology, mineral and ore occurrences and topography. These supportive materials include background information, lesson plans, activity outlines, guidelines to activities and assessment suggestions. They are not comprehensive guides to the broad topics; instead, they are designed to provide information and opportunities for discovery on focused topics. The lesson plans, activities, guides and student directions give specific examples of how they can explore each topic using the Google Earth API.

3.2.2. Interactive Mapping Tool

The second component, the Virtual Globe Frame, enables developers to embed Google Earth API, which may be resembled as a mapping and geographical information program, into web pages or web-based applications with the use of JavaScript coding. Since it enables scripting, it provides great potential for the development of educational and other material.

The Google Earth API allows access to spatially referenced data sets within the GIS database. This interactive web mapping tool gives students the ability to create maps and earth views by querying and overlaying geological units, topography data, mineral and ore occurrences etc. (Figure 4). In this section students select the region they want to study and the data sets they wish to view; they can query data to display certain criteria and they can alter the appearance of the display. The Google Earth API mapping tool can be used independently or be paired with the supportive materials provided in the user guides to create meaningful, inquiry-based activities for students.

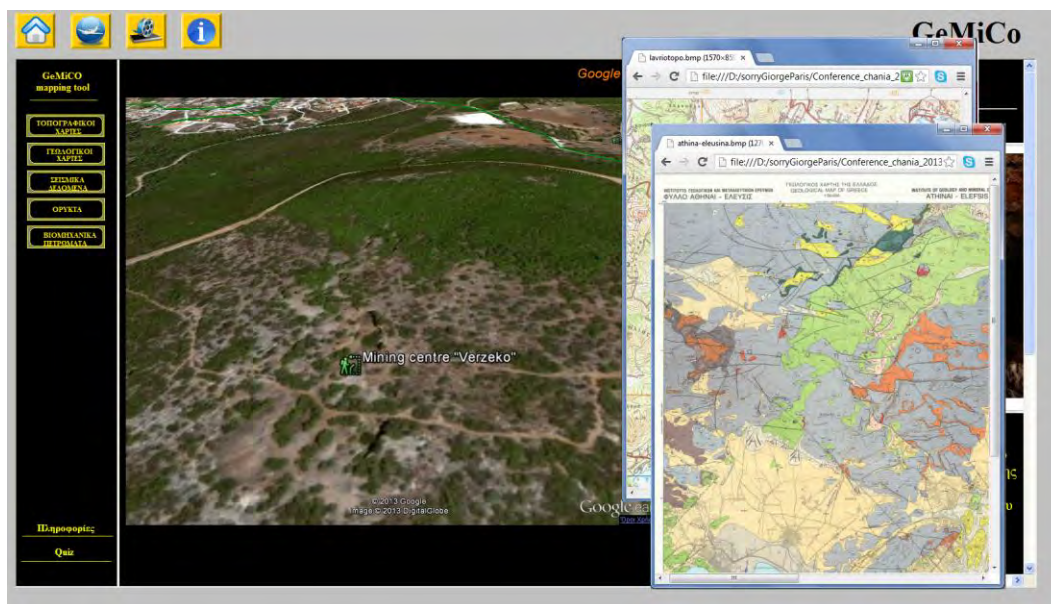


Figure 4 – GeMiCo Interactive mapping tool.

3.2.3. Multiple-choice quizzes and tests

The last component of GeMiCo Tool is the evaluation of the students' learning ability using multiple-choice quizzes and test. According to Crooks (1988), students study having in mind the way they will be tested. If they expect an exam focused on facts, they will memorize details; if they expect a test that will require problem solving or integrating knowledge, they will work toward understanding and applying information. Quizzes and tests are powerful educational tools and by utilizing them the educators achieve four important functions:

- Evaluate students' performance and assess whether they are learning what they are being expected to learn.
- Motivate and assist students to structure their academic efforts.
- Understand how successfully the material is being presented.
- Reinforce and continue the learning process by providing students with indicators of what topics or skills they have not yet mastered and should concentrate on.

The type of test that is most effective in motivating, measuring, and reinforcing learning is the Multiple-Choice Quiz. Zeidner (1987) reported that students prefer the multiple-choice format for examination, a similar result found by Taub & McRury (1990). This type of examination is easier to prepare (the right answer is already written down), questions and answers tend to be less complex than constructed response items, their perceived success rate is higher (some answers may be correct by chance), and incurs less anxiety than the essay type assessment. However, the multiple-choice examination does not seem to invite students to make an in-depth effort to study (Struyven et al., 2004).

In GeMiCo Tool, there is a set 7 multiple-choice quizzes with geological and mineralogical questions of different level of difficulty (Figure 5). The first quiz, Quiz A, is the easiest while the last, Quiz G the most difficult.

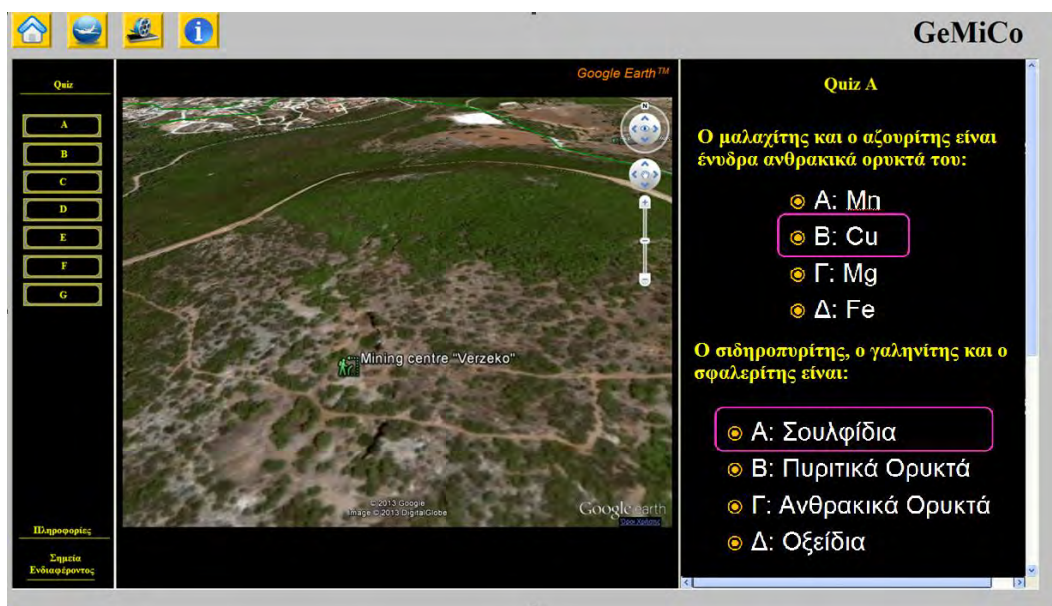


Figure 5 – Quiz pages.

4. Evaluating GeMiCo Tool

In order to evaluate the usage and effectiveness of GeMiCo Tool, a set of questionnaires and observations were analyzed. A small group of undergraduate students of the School of Mining and Metallurgical Engineering participated in the evaluation test, in the frames of the 1st semester course “Mineralogy”. The main goal was to learn how well the GeMiCO Tool is functioned in a classroom environment and how it is perceived by the students. The evaluation was accomplished using a student questionnaire and observations made by the educators. The distributed questionnaire was based on several evaluating methods of multimedia learning software (Croizat et

al., 2009). Table 1 shows the different evaluation criteria and sub-criteria used. Each sub criteria had a 5-scale rated value, where the lowest indicates higher appreciation by the users. The score of each user achieved during the tests was also analyzed as an indication of the learning power that GeMiCo Tool had. The total number of answered quizzes was 201, performed from a total number of 34 participants during the fall semester of 2012 (Table 2).

Table 1 - Evaluation criteria and sub-criteria.

Criteria	Description	Sub - criteria	
General Feeling	Takes into account the feeling the application gives to the user	Original Simple Active	Standard Complex Passive
Usability	Concerns the ergonomics of the interface of the application	Low level of guidance Low level of workload Low level of user control	High level of guidance High level of workload High level of user control
Multimedia documents	Concerns the quality of text, sound, animation, images, videos, 3D models, etc that are used.	Low quality of media Low level of information	High quality of media High level of information

Table 2 – Performance of students on quizzes .

Quiz (number of participants)	Right answers (%)
A (34)	88.34
B (34)	85.17
C (34)	86.12
D (30)	80.34
E (27)	81.24
F (23)	75.90
G (19)	71.20

5. Discussion and Conclusions

The technical affordances of cloud-based computing, digital textbooks, mobile connectivity, high-quality streaming video and “just-in-time” information gathering, have pushed great amounts of knowledge to the “placeless” Web. This has sparked a robust re-examination of the modern university’s mission and its role within networked society (Anderson et al., 2012). As the availability of computers and Internet connections in classrooms increases, the potential of harvesting such resources to advance teaching and learning provides unprecedented opportunities for both researchers and educators (Brindisi et al., 2006). According to Kali & Linn (2008), visualization plays an important role in assisting learning process since it makes, unseen and complex material, visible. By transforming certain content in a more animated format, it allows

users to have a better understanding of the concepts and to gain a more spherical and richer view of the process involving a specific issue. VG have opened the world of satellite images to the general public and allowed entertainment, education and exploration of new findings (Pringle, 2010). To the scientific community, VGs are not only tools that provide huge volumes of freely available images and 3D views of the Earth, but mostly, they are effective channels trying to distribute research findings, data and information. VGs offer researchers a naive alternative to the traditional GIS software, that leads to increased data sharing and facilitating studies at global scale (Yu & Gong, 2012). The presented educational tool assists students to observe satellite, aerial images and terrain models, but also 2-D and 3-D vector data concerning mining site locations, mineral resources, geological and mineralogical data and other related information. The visualization of such multi spatio - temporal data sources helps students to understand geological concepts and to achieve a better learning ability. From the analysis held concerning the distributed questionnaires to the students, the usage and the effectiveness of GeMiCo Tool was rated as valuable. Specifically, most of the students answered that, the general feeling GeMiCo Tool leaves, is that of an original, quite simple and active application. They appreciated the good level of the user control and the high level of the workload, although they ranked the tool with a low level of guidance. As for the level of data quality and information availability, the students ranked the tool with medium to good level. The performance of the students on tests indicated that the learning ability of GeMiCo Tool is thought to be significant high, specifically in low and medium level of difficulty. However, more comprehensive, multiyear and quantitative observations must take place in order to show the progress and learning gains GeMiCo Tool provide to students, with valid statistical indexes. Concluding, the specific features and capabilities of GeMiCo Tool that is appreciated with high value are:

- The ability to play the role of an unlocked gate of knowledge, since it allows user to collect data from the Internet and from user-specified layers of information.
- The ability to assist the learning process and enhance the ability to think spatially.
- The ability to explore dynamic events and (near) real – time data.

6. References

- Anderson Q.J., Boyles J.L., and Raine L. 2012. The future impact of the Internet on higher education: Experts expect more-efficient collaborative environments and new grading schemes; they worry about massive online courses, the shift away from on-campus life. Pew Internet & American Life Project, Available online at: <http://www.eric.ed.gov/PDFS/ED534048.pdf>
- Atkins D.E., Droegemeier K.K., Feldman S.I., Garcia Molina H., Klein M.L., Messerschmitt D.G., Messina P., Ostriker J.P. and Wright M.H. 2003. Revolutionizing science and engineering through cyber infrastructure: Report of the National Science Foundation Blue-Ribbon Advisory Panel on cyber infrastructure: Arlington, Virginia, The National Science Foundation, *The Directorate for Computer and Information Science and Engineering*, 84 p., <http://www.cise.nsf.gov/sci/reports/atkins.pdf>
- Bailey J. and Chen A. 2011. The Role of Virtual Globes in Geoscience, *Computers & Geosciences*, Vol. 37, No. 1, pp. 1-2. doi:10.1016/j.cageo.2010.06.001
- Blumenfeld P.C., Soloway E., Marx R., Krajcik J.S., Guzdial M. and Palincsar A. 1991. Motivating project-based learning: Sustaining the doing, supporting the learning, *Educational Psychologist*, 26, 369 - 398.
- Brindisi C., Seber D., and Moore A. 2006. Evaluating geosciences information systems in the classroom: A case study of Discover Our Earth, *Geosphere*, 2, 1-10.
- Brown M. 2006. *Hacking Google® Maps and Google® Earth*, Publisher Wiley, pp 408.
- Butler D. 2006. Virtual globes: the web-wide world, *Nature* 439, pp. 776–778.
- Crooks T.J. 1988. The Impact of Classroom Evaluation Practices on Students, *Review of Educational Research*, 58(4), 438-481.

- Crozat S., Hu O. and Trigano P. 1999. A method for evaluating multimedia learning software, *ICMCS '99 Proceedings of the IEEE International Conference on Multimedia Computing and Systems*, Vol1., 714-719.
- De Paor, D.G., Simpson C. and Whitmeyer S. 2008. Deconstructing Classical Geologic Maps Using Google Earth's Keyhole Markup Language, *Geological Society of America Abstracts with Programs*, 40 (6), pp 348.
- Janikian Z. 2009. Lavrion and surroundings. Series Geotrails in Greece: Ed. Theodosiou, I., IGME, Publ. Kaleidoskopio. ISBN 978-960-98903-2-8 in English and 978-960-87453-6-0 in greek.
- Kali Y. and Linn M.C. 2008. Designing effective visualizations for elementary school science, *The Elementary School Journal*, 109 (2), 181-198.
- Manduca C.A. and Mogk D. 2002. Using data in undergraduate science classrooms: Final report on an interdisciplinary workshop at Carleton College, Available at: <http://serc.carleton.edu/files/usingdata/usingdata.pdf>
- Pringle H. 2010. Google Earth shows clandestine worlds, *Science*, 329, 1008–1009.
- Rakshit R. and Himmelberger O.Y. 2008. Application of Virtual Globes in Education, *Geography Compass*, 2(6), pp 1995–2010, doi: 10.1111/j.1749-8198.2008.00165.x
- Struyven K., Dochy F. and Janssens S. 2004. Student's perceptions about evaluation and assesment in higher education: a review, *Assessment & Evaluation in Higher Education*, 30(4), 331–347.
- Traub R.E. and MacRury K. 1990. Multiple-choice vs. free response in the testing of scholastic achievement, in: K. Ingenkamp & R. S. Jager (Eds) *Test und tends 8: jahrbuch der pädagogischen diagnostic* (Weinheim und Base, Beltz Verlag), 128–159.
- Tsangaratos P. 2011. Virtual Globes and Geological Modeling, *International Journal of Geosciences*, 2(4), pp. 648-656, doi: 10.4236/ijg.2011.24066.
- Wernecke J. 2009. *The KML Handbook: Geographic Visualization for the Web*, Addison-Wesley, Upper Saddle River, p. 368.
- Wilson T., Burggraf D., Lake R., Patch S., Martell R., McClendon B., Jones M., Ashbridge M., Hagemark B., Wernecke J. and Reed C. 2008. OGCs KML. Open Geospatial Consortium, Document OGC07-147r2, pp 251. <http://www.opengeospatial.org/standards/kmlS>.
- Yu L. and Gong P. 2012. Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives, *International Journal of Remote Sensing*, 33:12, 3966-3986.
- Zeidner M. 1987. Essay versus multiple-choice type classroom exams: the student's perspective, *Journal of Educational Research*, 80(6), 352–358.