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GEOTOPOS – Supporting Geomatics Engineering Education with a knowledge database of Geosciences-based digital content

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Abstract: - Today's advances in digital information and communication technologies, especially in areas such as the World Wide Web accessibility and Web-mediated learning environments, provide a wide variety of means to support and empower the teaching, learning and training experiences of both the teachers and the learners in all levels of educational needs.

At the Department of Surveying Engineering of the National technical University of Athens, we are facing this challenge by developing GEOTOPOS, a repository of Geosciences-based digital resources, which are systematically organized for easy access, efficient search and intelligent navigation through the Web. GEOTOPOS would essentially evolve into a Digital Library for Earth System Education that will eventually support teaching and learning about the Earth as a system in general and Geomatics Engineering in particular.

This paper addresses key concepts and the architecture characteristics of GEOTOPOS, with emphasis on the models necessary to represent geosciences-based knowledge, which is accessed in most cases in terms of geographic content and relationships that, in turn, are creating special challenges and opportunities for networked information systems like the GEOTOPOS. It describes implementation details for the various components of GEOTOPOS, as well as discusses briefly both the lessons learned so far, and the future directions of our efforts.

Key-Words: - GEOTOPOS, Geosciences-based Knowledge Database, Digital Library for Geosciences Educational Content

1 Introduction

Geomatics Engineering is a modern discipline and the practical application of knowledge necessary for studying the geographic space that surrounds us. As such it integrates the acquisition, modeling, analysis, and management of spatially referenced data collected by terrestrial, marine, airborne, and satellite-based sensors. This knowledge comes from several geosciences-related disciplines, such as: Geodesy and Geophysics, Positioning and Navigation, Cartography, Digital Imaging and Mapping using Photogrammetry and Remote Sensing (e.g. images taken by airborne and satellite sensors), Geographical and Land Information Systems, Hydrology, Hydrography, Oceanography etc. It has applications in all disciplines which depend on spatial data, including environmental studies, planning, engineering, navigation, geology and geophysical exploration, marine sciences, land development and land ownership etc., and it is, therefore, fundamental to all the geoscience's disciplines that use spatially related data. For that reason, both educators and learners, as well as researchers and professionals who deal with the acquisition and use of Geomatics knowledge need to improve continually their understanding of the Earth as a system, to develop new methods of collecting, analyzing and interpreting geospatial data for specific applications and to keep up-to-date with the rapid growth of the know-how, methods and tools of these disciplines.

In response to these needs, the last few years, digital libraries, e-repositories and portals have been regarded as the ideal environment for structuring, gathering and accessing of information, while at the same time providing tools and activities that bring together collections of digital content, services, and contributors in support of the full life cycle (from creation, dissemination, use, and preservation) of data, information, and knowledge, and hence to facilitate all of the aforementioned educational goals, [1], [6]. More specifically, in relation to the special Geomatics Engineering needs, of particular relevance is their unique potential to address the special characteristics of Earth-related information, such as for example, cataloging and gathering of resources that broaden the use of Earth science data and data analysis tools in educational settings, as well as offering access to virtual environments that can be used effectively for 3-D visualization of Earth structure and Earth-related phenomena, modeling of open natural systems and understanding of complex interactions in global, regional or local cycles. Furthermore, they have the potential to increase the use of best teaching practices by providing the tools and data needed to build inquiry and discovery into all types and levels of teaching and learning activities.

2 The GEOTOPOS Project

Prompted by the concept of building a knowledge database combined with portal tools (e.g. a Content Management System, internal and external catalogues and metadata) that integrate and interoperate with digital library elements at a number of levels, at the National Technical University of Athens, we have recently been developing the GEOTOPOS. This is an educational Geosciences-based e-repository that is designed so as to allow learner's at all educational levels to discover and use of earth science related digital content by linking suitable services with the educational curricula and learner-centered data tools. GEOTOPOS is thus evolving as a hybrid digital library seamlessly integrating access to a wide range of digital Geomatics resources, local and remote, using a Web-based interface and in a way that is being capable of providing a resource-rich environment for Geomatics Engineering-related teaching and learning activities: from a single tutorial, a subject theme or a collection of materials relevant to an entire course at undergraduate or postgraduate level with particular emphasis on disciplines drawn from the spatial sciences.

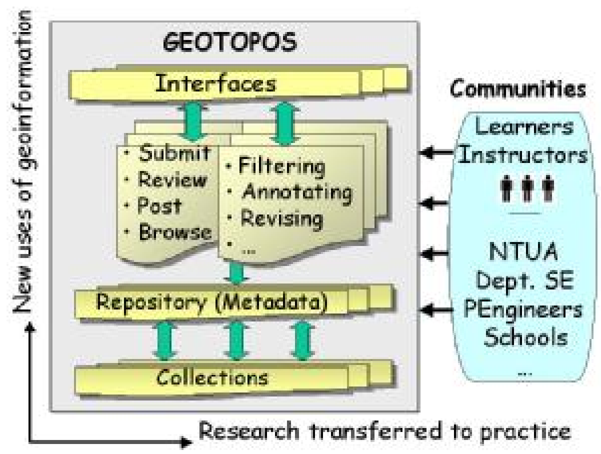

Fig. 1 – Schematic of the GEOTOPOS Information Model

Conceptually, the design of GEOTOPOS is based on the overall information model shown schematically in Fig. 1, which can be considered as a straightforward three-layer architecture consisting of: ***Interfaces***, a ***Knowledge Database (Repository/Metadata)***, and ***Collections*** of web-based digital content. This architecture also encapsulates the differing workflows needed by the GEOTOPOS' end-users for submitting, storing and retrieving available educational digital resources. In that way, it is envisaged that GEOTOPOS will eventually function as a knowledge database on top a digital library to be built around a "community" of educators and learners — encompassing faculty, students, and life-long learners. This is similar to the concept on which other more ambitious projects such as the *Digital Library for Earth System Education*—DLESE [3] or the MIT's *DSpace* Open Source Dynamic Digital Repository [4] are based.

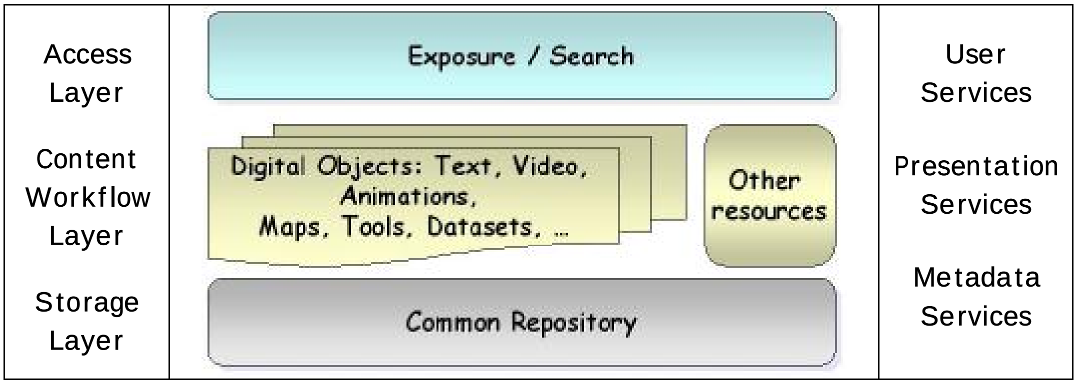

Fig. 2 – Schematic of the GEOTOPOS Technical Infrastructure

2.1 Technical Infrastructure

The overall GEOTOPOS system is being developed around a technical infrastructure that is in sync with the rapid changes occurring with state-of-the art research in databases, information retrieval, information technologies and digital libraries implementations. Along the way, we are also developing and implementing key elements specifically addressing the GEOTOPOS users' defined needs (e.g. types of digital content) that were established at the early stages of this development through surveys of the faculty and students in Geomatics Engineering education in our university. Thus, our design approach for GEOTOPOS is guided by the following basic principles:

- To expose the GEOTOPOS repository via web services interface;
- To use XML as standard for storage, and export of digital content, as well as standard means of encoding service requests and responses;
- To build various services and user interface layers, without any assumptions on particular use case or end-user experience.

This has resulted, as shown conceptually in Fig. 2, in a technical infrastructure composed of an ***Access Layer***, a ***Content Workflow Layer,*** and a ***Storage Layer,*** each underpinning a set of corresponding enabling services, i.e. the ***User Services***, the ***Presentation Services*** and the ***Metadata Services*** which provide the required functionality described in more detail in the next section. In broad terms, the GEOTOPOS' web-based services are designed with such criteria in mind as to:

- ***Enable multi-tier applications***, i.e.
    - Applications and other web services to interact with GEOTOPOS;
    - Data and digital content to be encoded and transferred using XML format standards;
    - Complex information fusion operations to be exposed, e.g. via XML Schemas, Collections/Multi-collections mining and reuse, Quality filtering, etc.
- ***Ensure Interoperability***, i.e.
    - Allow GEOTOPOS to run as a web-service in a distributed, operating-system independent environment;
    - Allow easy access from within GEOTOPOS to other similar geosciences-related repositories (e.g. DLESE)
    - Allow other digital libraries to easily access the GEOTOPOS digital content by taking advantage of the emerging commonality of capabilities, as a result of using accepted common standards, such as "Rich Metadata Descriptors" that would allow discovery and views of the GEOTOPOS resources.
- ***Reinforce Content-focused Models of Learning***, i.e.
    - By conceiving each of GEOTOPOS "digital objects" as both an *instructional resource* and as an *instructional entity*, thus providing access to new forms of information and knowledge (i.e. through virtual learning environments, recognition and extraction of valid knowledge from structured and un-structured digital data and materials, etc.).

2.2 Implementation Scope, Emerging Features and Functionality

Upon embarking on GEOTOPOS development, the initial goal was to create an open depository of our faculty's intellectual output in digital formats: research papers, educational instruction documents, datasets, images, audio/visual material, databases, or any other material it was deemed important. However, early on other categories of material, beyond faculty-authored documents and data, was decided to be included, such as: educational material in the form of courses-related web sites and online teaching and learning resources, and any valuable digital material supporting teaching activities (e.g. virtual lab materials, virtual fieldtrips, etc.). These can take the form of traditional lecture notes and e-books, sample exams, and course calendars, but also include other traditional tools like computer programming routines, modules and toolboxes, complex simulations and visualizations and the tools to create them, multimedia presentations, or educational videos, as well as maps, aerial photos and satellite images and geographic datasets in various forms.

2.2.1 From Digital Objects to Digital Collections

One of the most powerful concepts supported by GEOTOPOS is digital content modularity; that is, any of the aforementioned resources are stored as the individual elements that comprise the smallest resource units, the so-called "***Digital Objects***". These are essentially typical digital resources such as texts in various formats (e.g. text, pdf, html), videos, images and animations, simulations, maps, etc. that all have an educational context. Since these resources are digital, and available online, they can be used as originally intended or they can be altered or combined to meet the needs of other educators or to serve in different educational and learning contexts, thus becoming ***re-useable*** or ***re-purposing*** digital objects. Digital objects in GEOTOPOS can be further defined as Simple, Group and Complex objects as follows:

- ***Simple digital objects*** – i.e. resources that is intended to be viewed or used as one conceptual object, e.g. a Word document, a TIFF image, a Matlab module, a JavaScript, etc.
- ***Digital object groups or Digital Packages*** – These consist of a set of independent but related resources (i.e. simple digital objects) that are collectively described, e.g. a "Matlab Toolbox" containing several Matlab modules, each being accessible independently (as a Simple Object), but its relationship to other objects in the group provides valuable context, e.g. being useful for particular type of problems, such as Navigation, Filtering, Image Processing, etc.
- ***Complex digital objects*** – These consist of a group of dependent resources intended to be viewed or used as a single conceptual object, e.g. an entire web site, an e-book, or a library of computer resources, for which often there is only one entry point.

Special digital object groupings within GEOTOPOS are treated as collections of logically related material. ***Collections*** are digital resources grouped together because they are organized around a theme, a resource type or some other criteria. The determining characteristics of a collection *may* include resources that have a common format; topic coverage; geographic coverage; temporal coverage; pertinence to a particular study or project objective; source of origin; or physical location. For example, a Technical Report series, a series of Undergraduate Diploma Theses or Graduate Dissertations can be a collection. Or, a map series or sets of aerial photographs from a particular flight can be treated as separate sub-collections described through parent/child records within even larger collections, such as a *Map Library* or *an Aerial Photo Library*. In a broader sense, a collection can even be an organized or thematic group of information records, such as pointers to and information about web-based learning resources or an external portal, which GEOTOPOS does not actually hold but they may be distributed in many different sites across the World Wide Web.

In order to balance the need for an efficient e-repository of quality educational materials with the desire for community sharing of a wide variety of resources, the GEOTOPOS holdings will be divided into three main parts: *informal-*, *broad-* and *core-collections*, depending on the extent of the review process required in order that they become part of GEOTOPOS. Resources held in the core collections will be thoroughly reviewed to ensure that they are accurate, important, pedagogically effective, well documented (e.g. with metadata), easy to use, motivational, and robust. The broad collections will be less rigorously reviewed and are envisioned, in part, as a needed test bed for the development of the core holdings. Respectively, the informal collections will consist of earth-related resources that meet the minimum standard of relevance and appropriateness to Earth system and Geomatics Engineering education and have a minimum amount of associated content and context descriptions. Future action plans envisioned in this area, include a full range of communications tools to be developed for improving the quality of the individual resources including peer reviews, testing, and evaluation.

2.2.2 Digital Object Models

The digital objects in GEOTOPOS can be used as stand-alone resources or they can be suitably altered, combined or re-packaged to create new, customized resources, following the instructional concepts known commonly as the "*Learning Objects*" and the "*Knowledge-Objects*" respectively [2], [5].

The term "***Learning Objects***" generally applies to small instructional components of digital content that can be reused a number of times in different learning contexts, and for the purpose of maximizing the number of learning situations in which the resource can be utilized. Typical examples of Learning Objects include combinations of digital objects encompassing multimedia content, instructional content and learning objectives, instructional software and software tools, and data referenced during technology-supported learning. On the other hand, ***"Knowledge Objects"*** consist of a complete, discrete package of information/content (i.e. a small number of learning objects) that has a stand-alone meaning and/or representing a highly structured interrelated set of data, information, and knowledge. Therefore, knowledge objects can be thought of as the components of instruction that enable the learner to be more productive by providing the dynamic opportunity for repetition and review.

Reflective Observation Publications, Presentations, Demos, …	Þ	*Active Experimentation* Lab guides, experimentation, Simulation, …
Ý		ß
Abstract Conceptualization Theory, Modeling, Analysis, …	Ü	*Concrete Experience* Case Studies, Hands-on Activities, …

Fig. 3 – The Integrative Learning Model realized by utilizing GEOTOPOS resources in the form of Learning and Knowledge Objects

Use of the GEOTOPOS resources in the form of Learning and Knowledge Objects allows GEOTOPOS to serve as an enabler of technology-enhanced learning, as it enhances constructivist and experiential learning approaches. For example, by promoting integrative learning by cycling through the different cognitive models shown in Fig. 3, which are of particular importance to the learners of Geosciences and Geomatics Engineering, as well as a key element of success in their professional practice later on.

2.3 The Use of Metadata

Metadata are the key optional fields that are used to describe information objects in GEOTOPOS. They can be different in nature, such as fields containing mostly terminology (e.g. titles, key words), attributes (e.g., creator name), or more structured information (e.g., dates, format, subject categories) about a digital object. Thus conceptually, each digital object is a logical entity or data structure whose two principal components are digital content ("data"), already mentioned in 2.2.1, plus other information stored in the digital object that pertains to its properties and its content ("key-metadata") and is needed to manage the digital object in a networked environment. For example, a digital object representing a scanned image consists of two elements: its data, i.e. the image in tiff, gif, or jpeg format, and its metadata about the image, including descriptive and technical information, e.g. its quality indicators, time taken, etc. Generally, a digital object's associated key-metadata may be regarded as "handles" or "signatures" that uniquely identify the object or may also contain other information or properties, such as: description of access to the resource, licensing agreements relating to the underlying content, usage terms and restrictions, permissible operations, the sources and contributors of the underlying information components, the rights of each source and notices of ownership, the kinds of permissions that must be updated, and how to obtain these rights, etc.

2.4 Web-based Access and User Interfaces

There are three major types of user interfaces in GEOTOPOS, which are entirely web-based: one for system administrators, one for those involved in the submission process, and one for end-users looking for information.

For the development of the web-based environment of GEOTOPOS, we used the PHP (***Pre** Hypertext Processor*) scripting language, which is an object-oriented server-based language that is made available as *open source*. PHP is similar to JavaScript, since both give the possibility of incorporating small programs (*scripts*) within the HTML (*Hypertext Markup Language*) code of a web page.

As a database we use the MySQL Server, which is compatible with all the commonly used operating systems and satisfies completely the foreseen needs of GEOTOPOS. This part of the system consists of a central relational database that manages the individual sub-systems, their content and the user's privileges, as well as from a small number of individual sub-databases that manage the digital content of GEOTOPOS. The reasons that dictate the use of a robust structured query language (SQL) database to store and index the individual resources records, and hence as a mechanism for content management, are manifold; that is, such a system:

- Allows the possibility of handling easily a large number of digital content elements.
- Can easily allow changes to the organization of the databases without the need to change the mechanisms of storage and recovery of data.
- Avoids any restrictions due to the operational system being used.
- Allows simultaneous access to the system by several users, with different roles and, consequently, with different rights of access.
- Provides efficient mechanisms for searching within the database using specific and multiple criteria.

A user interacts with the GEOTOPOS through the various interfaces to one or more services supporting specific tasks, such as put, get, search, review, or provide specialized views of the available digital collections and the digital objects they contain. The various interfaces consist of all the tools necessary to provide typical digital library actions, such as the submission and manipulation of its digital objects and the way in which these tools can be used to perform these actions with minimal effort.

The functions of submitting a digital object to GEOTOPOS and managing these objects can be subdivided into three distinct, but also self-complementary categories: *metadata manipulation*, *data (digital content) handling*, and *repository management*. Typically, the submission of a digital resource is based, on the use of metadata templates containing specific information fields and background control vocabularies which provide complete description of the form and presentation of content in all categories and subclasses of resources of GEOTOPOS (i.e., from the level of digital objects up to the level of collections). This means providing information like a title, description, targeted usage, geospatial coverage, thematic keywords about classroom activities and curriculum context, annotations, etc. that can be used for knowledge discovery. The use of design templates, increases the ease of metadata creation while at the same time offers possibilities of using alternative forms depending on the category, the type and the intended educational level of content or even defining access levels of various categories of target-users (e.g. profile of users or team of users). Furthermore, these tools provide an easy way to input or modify the metadata describing a submission and also to upload the digital objects, as well as to inspect, commit or modify new submissions or old objects. They also allow differentiating among multilingual (e.g. Greek and English) or heterogeneous collection groupings, where the metadata fields describing each collection may be different.

Services interact with each other through metadata, keywords and meta-tags, which describe the relationship of the digital objects to one another in order to support discovery, use, and storage of those objects. Hence, the end-user interface supports search and retrieval of items by browsing or searching these metadata, keywords and meta-tags. Typically, users can search for specific digital objects in GEOTOPOS by thematic content, by type of resource and/or pedagogic category (e.g. course and seminar materials, presentations, quizzes, exams, homework tests etc.). Once an item is located, its retrieval is accomplished by clicking a link that causes the archived material to be "downloaded" to the user's web browser. "Web-native" formats (i.e. those which will display directly in a web browser or with a plug-in) can be viewed immediately; others must be saved to the user's local computer and viewed with a separate program that can interpret the resource (e.g., a Microsoft Excel spreadsheet, a PowerPoint presentation, etc.) or be manipulated by a specific application (e.g. a Fortran compiler, a viewer, etc.).

3 An Example Scenario of Usage

To understand the described features and functionality of GEOTOPOS, especially the concepts behind the use of learning and knowledge objects, and to appreciate their potential benefits, it is best to look at an illustrative real situation example pertinent to the education of surveying engineering students and to outline how the digital resources in GEOTOPOS can be used to construct suitable instructional units for diverse educational needs, learning styles and situations.

For example, consider a course instructor who can make use of a series of 360^o panoramic photos (i.e. *the digital objects*) in GEOTOPOS in order to create a composite image (i.e., *a learning object*) that represents and illustrates the space around a point (*i.e. the perceptual knowledge*). When using these panoramic scenes with a QuickTime tool or a Virtual Reality viewer (QTVR) (i.e. *another digital object*), a user can pan and zoom into the entire (composite) digital image, giving the impression that he or she is surveying the scene by turning around a fixed point. This panning operation is very similar to operating a Total Station (one of the surveyor's most commonly used instruments) at a point (i.e. a station or a node). That is, it can emulate the procedure of pointing the telescope towards a reflective target to make a measurement. Consequently, the physical process of moving the surveying instrument from one station to another can be considered similar to linking nodes so that to allow the user to jump from one panorama to another or equivalently creating a multi-node QTVR video clip to illustrate navigation from one viewpoint to another. For a different purpose, the same concept and tools can be used in a sense opposite to the previous panoramic photos usage, i.e. by using images of an object (e.g. the Total Station instrument, in this case) taken from the points on a full (imaginary) sphere around it. These individual images, stored in their correct order frame by frame, could be used to construct an object movie, which could allow future users to examine the "virtual Total Station" on a computer screen from all angles, i.e. to virtually turn it around in order to explore its parts and get familiar with its operation before actually getting any hands on experience with the use of a real instrument of the same type. Furthermore, combining such learning objects, one can simulate the entire process of locking onto a target, making angle and distance measurements through simulated total station controls, and traversing from point to point of a project area. Therefore, assembling these QTVR movies together, for example, with:

- a brief introduction to the surveying concept of traversing;
- a description of the parts of a real Total Station;
- a plan or a map of the "virtual" area to be surveyed by the traversing method;
- some basic Matlab modules or excel workbooks for performing traverse data computations;
- and an exercise on traversing involving real or simulated data,

can lead to a complete instructional/information package with delivery instructions that integrate seamlessly onto a knowledge-driven, scalable, and yet granular, educational resource (i.e. *a knowledge object*) that delivers valuable personalized and engaging learning experience. This example also illustrates clearly the education paradigm shift from "teaching" to "learning" that is made possible with the use of systems like GEOTOPOS.

4 Conclusion

From this early stage of its development, it is already evident that the GEOTOPOS can serve simultaneously as a system, a tool, and a platform for collecting, managing, indexing, and distributing educational content in digital form in order to enhance the traditional learning process and address multiple learning styles and needs, and hence, to satisfy the diverse knowledge management requirements relevant to Geomatics Engineering education. It also provides a way to manage selected research materials and publications of high quality and educational value, in a professionally maintained repository, and to give them greater visibility and accessibility over time.

The success of GEOTOPOS as a service depends not only on the development of a critical mass of content, but also on the development of a critical mass of users. The development of an on-line community — consisting of developers, educators, interested parties and learners of the content made available through GEOTOPOS — will provide the means of sustaining it as an educational valuable resource.

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Paper ID number	**Reviewer 1:**	**Reviewer 2:**
507-110	In the present work Delikaraoglou et. al., present GEOTOPOS. A database that supports Geomatics Engineering Education. The work is describes with a clear informative way the architecture characteristics of GEOTOPOS and presents the experience gained with its applicability in the Department of Surveying Engineering of the NTUA. The present work is an excellent example of the combination of digital and communication technologies with Earth Sciences education. I suggest a focus on this during the conference. Overall a strongly suggest the presentation of the present work to EE-2005	The paper under the title "GEOTOPOS – Supporting Geomatics Engineering Education with a knowledge database of Geosciences-based digital content" by D. Delikaraoglou, N.Kalogeropoulos, J.Tzigounakis and G.Souris addresses the key concepts and the architecture of a developed, web-based digital library, having the code name GEOTOPOS, comprising of diverse knowledge Geosciences databases and aiming to operate as an open and educationally rich and value-added repository with emphasis in Geomatics engineering education. The paper is accurately written using the WSEAS format. The subject presentation is considered very good and complete, highly fluent in English writing, divided to 4 main sections (including Introduction and Conclusions) where a general schematic project overview is given concerning information model adopted and the technical infrastructure implemented and a description of the various digital content modules together with their information objects (metadata) and modes of use (Integrative Learning Model) are provided and adequately covered. A scenario of educational usage is given as an example but the aimed, by the authors to be demonstrated, multipurpose exploitation of the same content and tools is not so evidently presented to the reader. In an extended version of the paper I would suggest the authors to include a brief comparison with other existing digital libraries (focusing on advantages, ameliorations and innovations that GEOTOPOS offers, if any), a more detailed reference to the actual scientific and educational content of its digital objects and collections and some discussion on the results of the project implementation, concluded usefulness and effectiveness in engineering education up to now. I highly suggest to be accepted in the Engineering Education Conference.