Development of a Learning System to Introduce GIS to Civil Engineers

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Abstract: A learning system to facilitate the integration of Geographical Information Systems (GIS) into the Civil Engineering curriculum is described in this paper. The principal learning goal is to encourage students to apply and integrate foundational knowledge in the solution of "real world" comprehensive civil engineering problems (e.g., geotechnical). GIS software is a necessary tool for the solution of these integrated problems in the modern civil engineering workplace. At the heart of the learning tool is the problem to be solved, which requires the use of the GIS software. Sharable content objects, designed in accordance with the ADL/SCORM standards, contain basic knowledge components necessary for utilizing the GIS software. Additional detail is presented for one of the learning objects, which uses an applet that simulates a commercial soils laboratory where the students submit orders and are delivered data results with an invoice.

Introduction

The Civil Engineering program at the University of Missouri–Rolla has an initiative to explore ways to integrate Geographical Information Systems (GIS) into existing curriculum. To this end a proof of concept project was initiated to develop a learning system to be used by professors in their classes. GIS is not a topic traditionally taught in civil engineering programs. However, computer advances and the proliferation of available GIS software packages have made this technology very popular in industry. GIS allows data management and analysis of spatial data in a computer and provides the engineer with a birds-eye view of complex problems in the form of a map. Civil engineers particularly work with data that is distributed spatially as city engineers, plant engineers, transportation engineers or other. If the student can graduate with a working knowledge of GIS, they open other opportunities in industry.

This paper describes the convergence of different streams of research and activity associated with learning technologies at the University of Missouri – Rolla. First, the Center for Technology-Enhanced Learning (CTEL) has begun the process of creating an Advanced Distributed Learning/Sharable Content Object Repository Model (ADL/SCORM) compliant repository for learning objects, a process referred to as the Learning Object Repository Initiative (LORI). The project has many components including the examination of this important ADL standard, review of existing supporting technologies, and the creation and modification of learning objects associated with a number of collaborative CTEL projects. For the past few years, the Laboratory for Information Technology Evaluation (LITE) has been carrying out research on a learning design approach referred to as *Progressive Scaffolding*. Progressive scaffolding is a technique in which students are provided with flexible guidance via media that differs in levels of abstraction and richness. Initial research results are interesting and promising and some of these are used in the learning system presented herein.

These research activities have come together through the collaboration for the development of a web-based learning system to direct students in understanding how to apply GIS within the context of real problems. The design of the system is guided by the progressive scaffolding technique within the context of SCORM compliant learning objects. The project, which began of February of 2004, involves the collaboration of computer scientists, information scientists, and civil engineers, and is partially supported by a grant from the National Science Foundation's Course, Curriculum, and Laboratory program (Award No. DUE-0341016). The learning system is described from a conceptual point of view and is presented bottom-up, from the learning objects to the full-application functionality.

Learning Objects and SCORM Compliance

The goal of distributed learning networks is to provide a repository of sharable learning objects facilitated by information networks. Conceptually, this means that educators decompose their courses into a collection of fundamental elements, called *learning objects*, and make them available to an information network (Committee, 2002). A learning object is a collection of web displayable material that has an associated learning objective. There are several goals to such a system. For the objects themselves, it is desired that they be *interoperable*, *accessible*, *durable*, and *reusable* (Englebrecht, 2003).

Key to the success of a distributed learning environment is having a common architecture shared across the network to ensure the interoperability and accessibility of the learning objects. In 1999, Executive Order 131111 tasked the Department of Defense (DoD) "to develop common specifications and standards for technology–based learning" ((ADL), 2004) resulting in the first draft of the *Sharable Content Object Reference Model* via the DoD's Advanced Distributed Learning Initiative. The fundamental idea behind SCORM is to use XML to attach metadata tags to content objects. Using these tags, information networks can access and distribute learning objects to a variety of educational environments using *Learning Management Systems* (LMS).

The primary user of SCORM–compliant distributed learning networks has been the military. The Army has seen remarkable success with its Distributed Learning System (Chisholm, 2003), with cost savings resulting in millions of dollars. However, university educational information networks have been slow to adopt and utilize these standards (Cheese, 2003). One hindrance is that professors are reluctant to view themselves as "content–providers." Another fundamental difference between military and academic use is that military tends to train whereas professor strive to educate. While training tends to emphasize acquiring skills through rote memorization and repetition, education seeks to carry the student through a guided exploration leading toward self-discovery. Since the concept of learning objects has been utilized primarily by the military, most of the key ideas associated with object formation, such as granularity and classification, lean toward training. The GIS project is proving to be an excellent translation project because it is a mixture of education and training. At the training level, the learning objects need to teach the civil engineering student in the use of the GIS software. At the education level, the learning objects need to guide the students through a solution path associated with a substantial civil engineering application. Hence, the lessons learned from the military's development of learning objects can provide a basis for evolving their role into becoming more educationally-oriented. This is a fundamental goal of LORI.

Progressive Scaffolding

Description

Progressive scaffolding is a term we use to refer to a systematic method of providing users with an optimal level of assistance. Within such a system, different levels or tiers of facilitation are provided to match the optimal levels of assistance required. The level could be set by the learner, an instructor, or automatically, based on learner response.

It's important to note that scaffolding, as defined within our framework, refers to guidance that supports the core content, which remains constant across differing levels of scaffolding. Therefore, the degree of scaffolding is not equivalent to difficulty of the content; rather it refers to the degree of supportive context provided. More specifically, in our research the scaffolding dimension has been represented by the media in which the content is embedded: plain text, text with graphics, or video. Thus the scaffolding differs in the degree of abstraction, fidelity, and richness.

Experiment 1: Pilot Exploration of Different Types Media Scaffolds

As one part of the Learning Object Repository Initiative described above, we are developing a series of learning modules based on the progressive scaffolding approach as support for a class in Web Development and Design. As a component of this system, we created a prototype module, which is a step-by-step description of how to create a fairly elaborate web page using the web development tool, *Macromedia Dreamweaver©*. To create the page, the user must apply a number of general procedures including: setting up a site, adding tables & graphics, using tables for page layout, inserting text, creating hyperlinks, creating image rollovers, and creating a disjoint swap image behavior.

This initial prototype system is straightforward and was intended to examine the key components of the model posed above. The progressive scaffolding is provided in the form of different levels of information for displaying each step in the development process: a) Text; b) Graphics; c) Narrated Video. The system used for the pilot experiment can be viewed at: *http://campus.umr.edu/lite/web_dev_experiment*.

A pilot study was carried out using this system including detailed quantitative and qualitative analysis of participants using the system to create a basic web site (Hall, Digennaro, Ward, Havens, & Ricca, 2002, 2003). This pilot study addressed the following two questions:

1. To what extent do users utilize the different scaffolding options (text, graphics, and video)?
2. How does their use of the various options relate to performance?

With respect to our basic experimental questions, we found that users primarily utilized the most minimal (text) and elaborate (video) scaffolds, while they largely ignored the static graphics. In addition, we found that the amount of time spent viewing the text was positively related to performance; while the time spent viewing the videos was negatively related to performance. Other important findings, which were not directly addressed via the experimental questions, emerged as well based on the qualitative analysis. One of the strongest findings was that the previous content knowledge (experience level) of the user played an important role, with the more experienced users utilizing the more minimal scaffolds to a greater degree. This helped to partially explain the strong negative relationship between the amounts of time spent viewing the videos and performance. The videos most likely did not "cause" poor performance, but were more useful to those with less experience. Unfortunately, this experiment did not allow for adequate evaluation of static graphics as scaffolds, since these were accessed so infrequently. Such an evaluation would have important practical implications, given differences in resources and complexity associated with the development and display of static graphics versus video.

Experiment 2: Comparison of Video vs. Static Graphics as Scaffolds

A second experiment was conducted, which extended the first in a number of ways (Hall, Stark, Hilgers, & Chang, 2004). First, a new prototype tutorial was created based on a newer version of Dreamweaver© (*http://campus.umr.edu/lite/scaffolding2*). In addition, the task participants were to perform was more self-contained, focused, and realistic than the previous experiment. Second, the number of students who participated was almost tripled (from 7 to 20). Third, and most fundamental, two experimental conditions were created, so that participants either used graphics as an adjunct scaffold to the text, or they used a video, rather than having the option to use both. This allowed for the direct comparison of graphics versus video as a scaffolding technique. Fourth, a pre-questionnaire was used which assessed participants' experience with *Dreamweaver©* in particular and web development in general, which allowed for a more thorough examination of the role of user experience in it's impact on the users' use of the tutorial and performance.

More specifically, the experiment addressed the following experimental questions:

1. How does time allocation (as measured by time spent on text, media, and task performance) differ as a function of experimental condition (graphics versus video)?
2. How does performance (as measured by quality, quantity, and ease-of-navigation) differ as a function of experimental condition?

3. How do users' subjective-ratings of the effectiveness and usability of the learning system differ as a function of experimental condition?
4. What is the relationship between degree of previous experiences and time allocation?
5. What is the relationship between degree of previous experiences and performance?

Once again, a detailed quantitative and qualitative usability analysis was conducted. With respect to the first experimental question, there was very little difference between the two experimental conditions in terms of the amount of time they spent on the different types of scaffolds. However, it was interesting to note that, in general students spent most of their time reading the text and carrying out the task, as opposed to using either the video or graphics. With respect to the second and third experimental questions, which involved the degree to which the different scaffolds differed, the bulk of the evidence indicated that those who had the video as a supplemental scaffold performed better than those who had the graphic screen shots. This is particularly interesting, given that the scaffold of choice (the text) was the most abstract with respect to exactly what the user was to do. Perhaps this indicates that, if a user needs to rely on additional media, more rich and representative media is preferred.

The fourth and fifth question addressed the impact of previous experience on time allocation and performance. A reasonably strong positive relationship was found between experience with *Dreamweaver*© and time spent on the task, while a strong negative relationship was found between *Dreamweaver*© experience and the time spent reading the text directions. Not surprisingly, as experience ratings increased, users tended to focus more on the task and less time reading directions. Also, consistent with expectations, across all measures, those with more experience performed better.

Application: GIS for Civil Engineering

GIS is a computerized database management system that provides geographic access (capture, storage, retrieval, analysis and display) to spatial data. While the industry sector of civil engineering has begun the process of integrating GIS within itself, the academic world has been slower to respond. Since civil engineering is replete with uses for GIS functions, public agencies' (the civil engineer's primary employer) use of GIS technology is increasing rapidly. There exists a consequent need for civil engineers versed in GIS and able to apply GIS tools to civil engineering problems in innovative ways. The University of Missouri – Rolla was recently awarded a National Science Foundation Curriculum, Course, and Laboratory Improvement (NSF/CCLI) planning grant (Award No. DUE-0341016) in order to create a prototype of such a learning application. From the outset we are working to break content into sharable content objects, and to utilize progressive scaffolding as an important aspect of the object management design.

In this proof-of-concept project begun in February 2004, the learning system being developed for the civil engineering curriculum focuses on a geotechnical application. The prototype consists of a comprehensive problem and an associated repository of learning objects organized using progressive scaffolding (Sullivan et al., 2004). Figure 1 represents a schematic of the basic system framework. The system consists of three parts, foundational knowledge in civil engineering, foundational knowledge in *Arcview*©, which is a popular GIS software application, and an applied problem. The system will be used in classes where students are already knowledgeable in the civil engineering concepts, so modules for these components will not be developed as part of the prototype, though they may be developed in later iterations. The students' knowledge of GIS is diverse, since the classes where the system is to be used are multidisciplinary with students from various engineering disciplines. Therefore, the GIS modules are an important part of this prototype system. The learning objects are to be organized as scaffolded media; designed so they will be applicable to students with different levels of knowledge. Novice students may require very rich scaffolding in the form of videos illustrating how to use the software, while other students may require less elaborate scaffolding in the form of text directions, while others may not require any extra guidance at all.

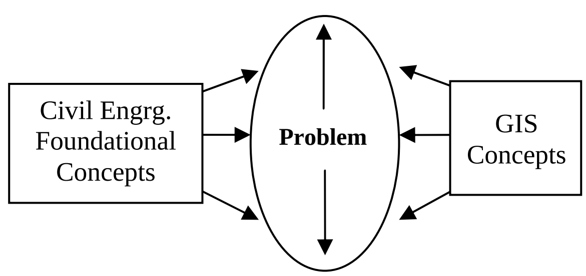

Figure 1: Learning System Model

The applied problem will be at the heart of the system, with the GIS learning objects providing support as needed. For the prototype, the basic problem will involve the creation of a structural landfill. Figure 2 is a flow chart which represents a portion of the problem.

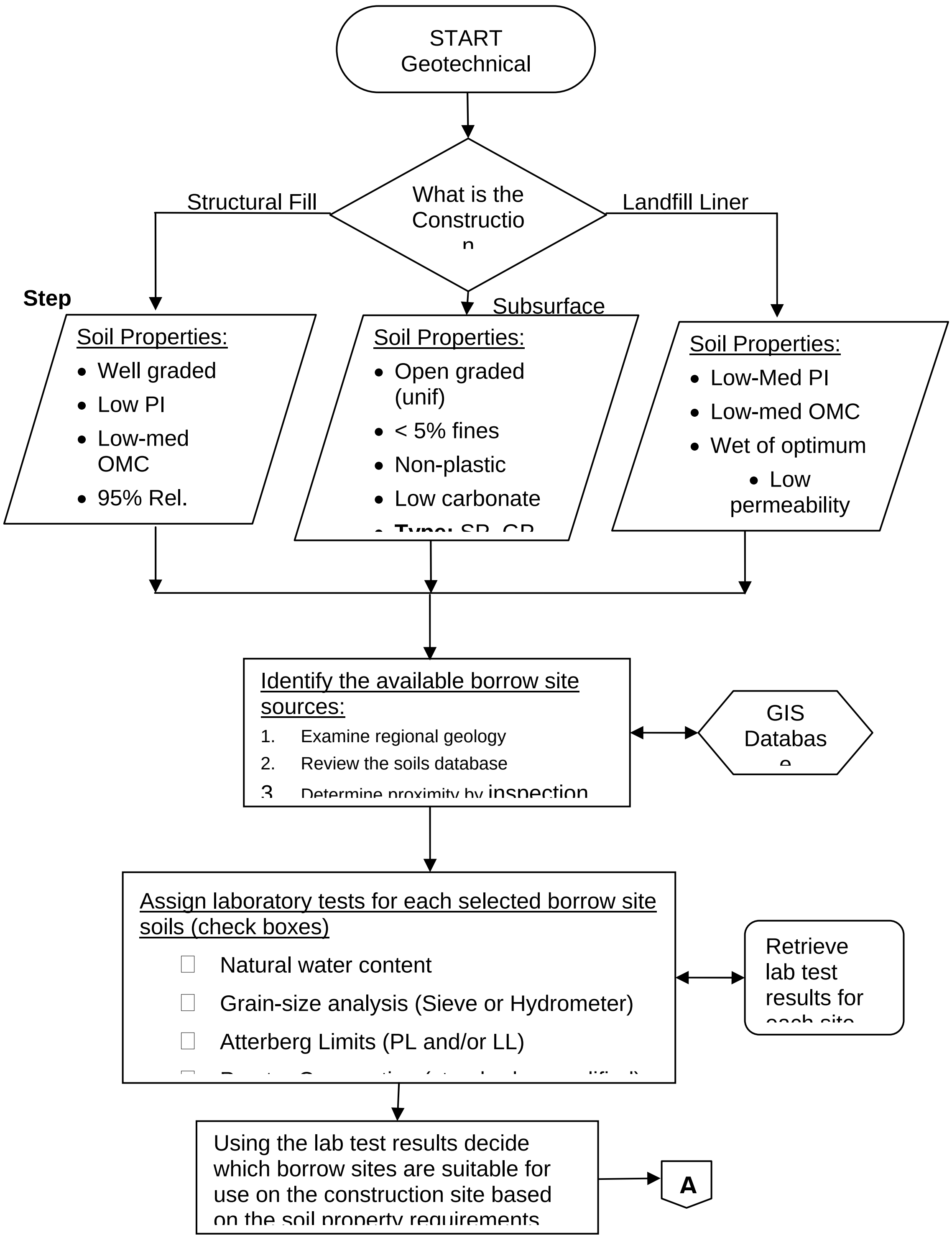

Figure 2: Flow chart of GIS problem

As a first step in learning object development, an "Arcview Basics" learning objects was created consisting of nine content objects. These content objects consist of a text and video representation of the following topics: opening a map, displaying labels, arcview navigation bar, and adding layers. The ninth object is an interactive video quiz, utilizing screen capture of the arcview interface. The learning object is SCORM compliant, including the interactive video quiz. The videos and quiz were created with *Macromedia's Robodemo*©. Figure 3 Consists of a screen shot from one of the screens of plain text, and a screen shot from the corresponding movie. The text and video components of this learning object can be found at http://campus.umr.edu/lite/gis, as well as a ZIP file containing the SCORM compliant object.

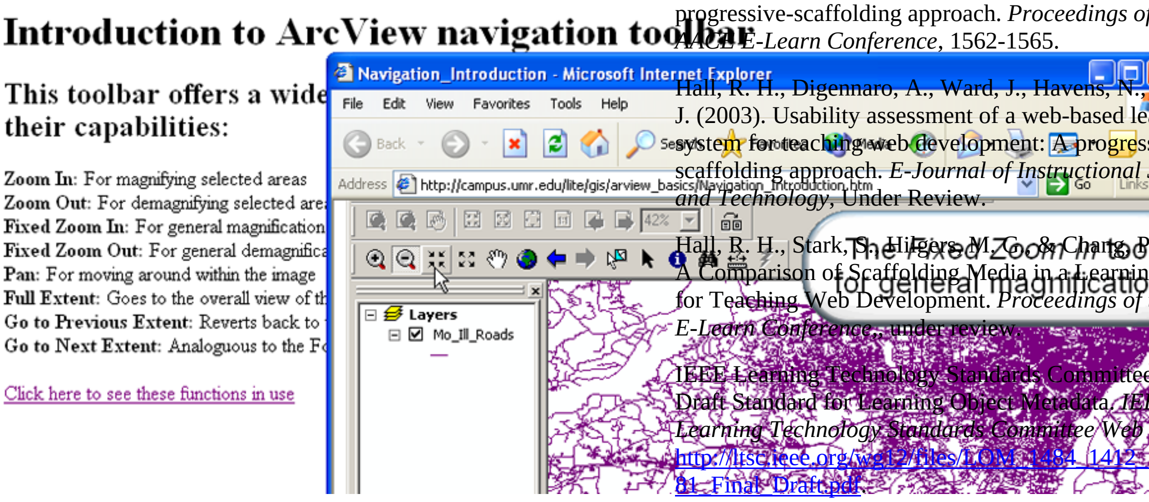

Figure 3. Screen shot of a portion of the text and video presentations of the Arcview Basics Navigation Content Object

Next Steps

Over the course of the summer of 2004 the prototype learning system will be developed. This development will consist of the development of the problem as well as the remaining foundational Arcview/GIS learning objects. Concurrently, initial usability testing will begin in order to examine the effectiveness of alternative interface and navigational schemes. The initial proof-of-concept project will conclude in the fall of 2004 with one or more applied assessment studies conducted within the context of laboratories for an undergraduate class in geotechnical engineering. The results of these studies will, in turn, inform the final modification of the prototype, and the initial design and development of a more complete system.

References

A. D. L. (2004). SCORM Past. *Advanced Distributed Learning Web Site*, http://www.adlnet.org/index.cfm?fuseaction=scormhist.

Cheese, P. (2003), "What Keeps Universities from Embracing e-Learning?," Learning and Training Innovations, November 5.

Chisholm, P. (2003), "Learning From a Distance," *Military Training Technology*, Vol. 8, Is. 4.

Englebrecht, J. (2003). Implementing SCORM in Enterprise Distributed Learning Environments. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference*.

Hall, R. H., Digennaro, A., Ward, J., Havens, N., & Ricca, J. (2002). Development of a web-based learning system for teaching web design and development: A problem-based, progressive-scaffolding approach. *Proceedings of the AACE E-Learn Conference*, 1562-1565.

Hall, R. H., Digennaro, A., Ward, J., Havens, N., & Ricca, J. (2003). Usability assessment of a web-based learning system for teaching web development: A progressive scaffolding approach. *E-Journal of Instructional Science and Technology*, Under Review.

Hall, R. H., Stark, S., Hilgers, M. G., & Chang, P. (2004). A Comparison of Scaffolding Media in a Learning System for Teaching Web Development. *Proceedings of the AACE E-Learn Conference*., under review.

IEEE Learning Technology Standards Committee (2002). Draft Standard for Learning Object Metadata. *IEEE Learning Technology Standards Committee Web Site*, http://ltsc.ieee.org/wg12/files/LOM_1484_1412_1481_v1481_Final_Draft.pdf.

Sullivan, J. M., Hall, R. H., Luna, R., Hilgers, M. G., Taylor, A. J., & Buechler, M. R. (2004). Degree of scaffolding as learning object metadata: A prototype learning system design for integrating GIS into a civil engineering curriculum. *Learning Technology, 6(2)*, 60 - 64.

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