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Evaluation of a Learning System to Teach GIS for Civil Engineering

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ABSTRACT

An evaluation was conducted on a web-based e-learning system designed to facilitate integration of Geographical Information Systems (GIS) into the Civil Engineering curriculum. The principal goals of the evaluation were to determine the overall effectiveness of the system and to better understand underlying learning processes. Data were collected from 80 students who participated in a computer laboratory session involving a typical geotechnical exercise. Students rated their learning and motivation significantly higher than studying from the class text, and rated the lab's applicability to the "real world" significantly higher than the class text or lecture. Furthermore, students rated their knowledge of GIS significantly higher after the lab session. Qualitative analysis indicated that students were motivated to use the system in order to develop a broad overview of GIS, to learn specific GIS functionality, and as a method for on-going review of GIS.

Keywords

GIS, learning technology.

INTRODUCTION

Geographic (or Geographical) Information Systems (GIS) have been defined in many ways. Environmental Systems Research Institute (ESRI), an industry leader in GIS software and geo-database management application, defines GIS as, "An organized collection of computer hardware, software, geographic data, and personnel designed to effectively capture, store, update, manipulate, analyze, and display all forms of geographically referenced information" (ESRI, 2008). Star and Estes (1990) defined GIS as, "A system that is designed to work with data referenced by spatial or geographic coordinates. In other words, GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with data. In a sense, GIS may be thought of as a higher-order map". We could call these *data driven maps*. In addition, Maguire (1991) identified two perspectives for describing GIS, the technological and organizational.

Initially developed by government agencies and later by private industry to store, organize, and analyze data that can be described or modeled spatially or geographically (Black, MacDonald, & Black, 1998), GIS is now being utilized in various disciplines (Francica, 2000; Lubenow & Tolson, 2001; Hockstra & Mattejat, 2002). Civil engineering projects are most successful when they involve the management, analysis, and integration of very large amounts of spatially distributed geographic information (Tandon et al., 2008). In sharp contrast to the proliferation of GIS implementation in the industry sector, academia has been slow to respond to these advancements. Integrating GIS concepts into civil engineering education is not only important to meet the urgent needs of non-GIS professionals in engineering, but also to teach students relevant skills in spatial analysis, reasoning and data processing (Easa et. al., 1998). Furthermore, integrating GIS into the curriculum may encourage students to examine data from a variety of disciplines (Furner and Ramirez, 1999; Sarnoff, 2000).

The learning system that was evaluated for this project consisted of a comprehensive problem and an associated repository of learning objects designed using a method referred to as progressive scaffolding (Hall, Watkins, & Eller, 2003; Hall, Digennaro, Ward, Havens, & Ricca, 2002; Hall, Stark, Hilgers, & Chang, 2004; Sullivan et. al. 2005). In progressive scaffolding, students are provided with different levels or tiers of facilitation to match the optimal level of assistance. In the current learning system, at the core of each module is a problem, which requires the learner to actively integrate knowledge from multiple sources and apply basic methods and procedures for its solution. Therefore, the degree of scaffolding is not concerned with the difficulty of the content, but refers to the degree of supportive context provided, e.g., plain text vs. video.

The overall objective of this project is to develop a number of discipline specific learning modules in geotechnical, transportation, water resources, surveying, and environmental engineering in order to expose this tool to students in civil engineering without increasing the number of courses or credit hours.

The goal of this research is to evaluate the effectiveness, and underlying learning processes associated with the geotechnical module. In order to realize this evaluation of the system, two approaches were used. One was a quantitative analysis of survey responses to Likert-scale questions. The other was a qualitative open-coding analysis. This approach is used to inductively develop categories and themes that emerge from the qualitative data allowing one to explore fundamental learning processes in more detail. The qualitative data consisted of transcripts from interview sessions, field notes gathered during the data collection stage, and answers to an open-ended question included in the survey that the students completed.

METHOD

Participants

The participants for this research were undergraduate students enrolled in a sophomore course "CE 215: Fundamentals of Geotechnical Engineering" at a technological research university in the Midwest.

Materials

The participants for this research were asked to use the GIS learning system as part of solving a specific problem related to soil borrow site selection; whereby introducing the students to the basics of how to use the GIS software. This web-based learning system consists of a series of *learning objects* designed to aid the students in using commercial GIS software (ArcGIS/ArcMap). A learning object is a collection of digital materials – pictures, documents, simulations – coupled with a clear and measurable learning objective or designed to support a learning process (Johnson 2003). In this environment, a learning objective can be to understand the steps of a tutorial or solving an exercise. The system also provides the context for the use of ArcGIS/ArcMap by including an overarching problem to be solved, in this case, soil borrow sites. The web interface listed information in two columns (Figure 1).

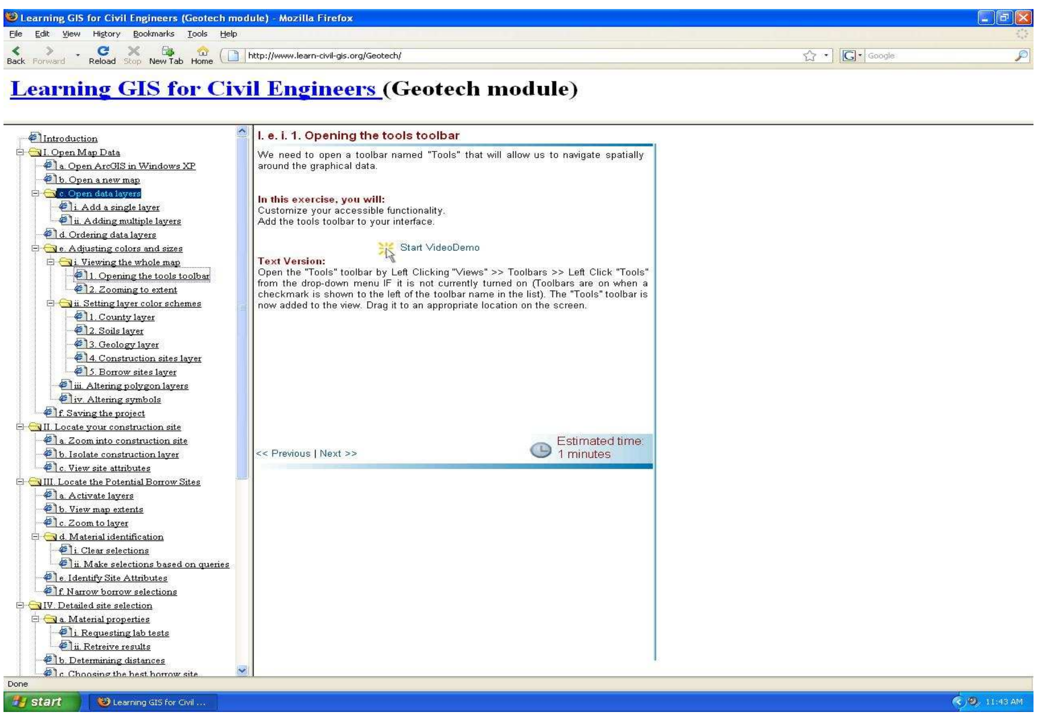

Figure 1. Screen shot of GIS Learning System

There are 47 instruction pages pertaining to solving soil borrow site selection problems as well as problems related to translating ArcGIS data into useful information. As a side-note, these pages are a form of learning object possibly containing other smaller learning objects. The left column provides access to these objects. It consists of collapsible navigation components. Consistent with the progressive scaffolding approach, the right side of the screen displayed a text version of the activities necessary to carry out the exercise as well as the link for the video version. One of the exercises consisted of going to a virtual soil analysis webpage that would send the results for the requested soil test to an email address provided by the participant.

Procedure

Students from the "Fundamentals of Geotechnical Engineering" class were organized into six different groups for lab sessions. Two sessions were carried out each day from Monday through Wednesday. Each session was 2 hours long. In the laboratory assignments covered in this evaluation, the students were provided with printed instructions before the start of the laboratory session. The objectives of the laboratory session were to: 1) Define what are the engineering objectives and material requirements for a construction earthwork operation; 2) Select the appropriate borrow sites for a particular construction site; and 3) Use a Geographic Information System for the selection of a borrow site and preliminary cost estimate. Students used computers with preinstalled GIS software (ArcGIS/ArcMap) along with the learning system open in the web browser. The students had to download a data set and then proceed to the tasks at hand.

The project's deliverables included a formal memo describing the reason for the selection of the site, results from the soil test, materials and delivery costs as well as the GIS map of the construction and borrow site along with appropriate data. Students were allowed to work with another person if they preferred. The students had the option to submit the deliverables at the end of the lab session or submit it in class the next day.

A day after completing the lab exercise, students filled out a questionnaire. It included a series of 9-point Likert-scale questions ranging from 1 (strongly disagree) to 9 (strongly agree), each followed by an open-ended question. The Likert-scale questions were intended to evaluate a student's perception of the laboratory activity in terms of learning, motivation and real world application, relative to other class components (text & lecture). In addition to the Likert-scale questions, each of which included an area that students could use to discuss their response, there were two specific open-ended questions pertaining to strength and weakness of the laboratory activity.

Interviews were also conducted to gain better understanding of students' experience with the lab sessions. Fifteen students were interviewed for data collection and their discussion was later transcribed. The researchers also observed the students during the lab sessions and collected field notes.

Students' response to the open-ended questions on the questionnaires, interview data and field notes constituted the data for the qualitative analysis.

QUANTITATIVE RESULTS

The survey included three sets of questions pertaining to perceived learning, motivation and real world application. In each set, students were asked to rate class lecture, class text, and the learning system. A series of three one-way within-subject analyses of variance were performed in order to compare the GIS learning system laboratory with class lecture and text. In each of the analyses of variance, course component (lab vs. lecture vs. text) served as an independent variable and rating as the dependent variable. All three analyses of variance were significant. The means and results of Tukey post-hoc tests are displayed in Table 1.

	Lab	*Lecture*	*Text*	*Post Hoc*
*I learned a great deal of information about soil borrow site selection from …**	5.600	5.138	4.250	Lab, Lecture > Text
*I found ... on soil borrow site selection to be very motivational**	4.650	4.275	3.638	Lab, Lecture > Text
*… over soil borrow sites was applicable to "real world" engineering**	7.588	6.125	5.112	Lab > Lecture > Text

* $p < .05$

Table 1: Means and Post Hoc Tests Comparing Survey Ratings

In the questionnaire, students also had to rate their knowledge level before and after the laboratory activity ("Before the lab activity that covered soil borrow sites, I knew a great deal about the subject area" vs. "After the lab activity that covered soil borrow sites, I knew a great deal about the subject area"). A one-way repeated-measures analysis of variance was conducted with perceived knowledge (pre vs. post) as the within subject independent variable and rating as the dependent variable. The results indicated that students rated their knowledge after the lab (Mean = 6.63) significantly higher than before (Mean = 4.54) ($p < .05$).

QUALITATIVE RESULTS

Sample and Data Resource

There were thirteen Likert items in which students could explain their answer. The two open-ended questions asked students to list the strengths of the lab activity and the ways in which the lab activity could be improved. Students' answers to the open-ended questions, interviews from the fifteen students, observation by the researchers, as well as the field notes made by the researchers were used in qualitative data analysis.

Open Coding

The qualitative data were analyzed following the open-coding approach. To establish reliability for the concepts generated during the open-coding, two researchers coded the first fifty-nine comments made by the participants. The third researcher tallied the concepts generated by the previous two researchers. The accuracy was 81.355%.

Students highlighted a number of factors that determined how they felt about the learning system, what they wanted from it and what they gained from their experience. Using open-coding, three different ways of using the GIS learning modules were identified: (1) *Broad Overview of GIS,* (2) *Specific GIS Functions, and* (3) *GIS Review.*

1) Broad Overview of GIS

Participants mentioned general understanding with GIS as the prime motive for using the GIS learning system. By utilizing this system, students are able to acquire a general understanding of the GIS concepts anytime at home, lab or at work. Students, as well as fresh graduates, are able to develop this general understanding by visualizing, manipulating and computing information within the GIS software. As one student mentioned, "*you can have basic understanding of GIS technology with this (GIS learning module). If you want the basic know-how with manipulation, you could do it anytime*." Another participant mentioned he could gain a general understanding of GIS when doing group projects, "*if you want to have general understanding of how to calculate and how to visualize problem properly in GIS, you have instant access to it*."

2) Specific GIS Functions

Using GIS, one can analyze and manage data in a variety of way. The GIS learning objects not only consist of general tasks, but also some high level data manipulation tasks. One can easily perform operations on maps and perform queries. According to one of the students, "*you can analyze and manage data in so many ways. This (GIS module) would be tremendously helpful in my further quest for GIS and you can do it at any place, at your own time*." Another mentioned, "*As a student, these would be very helpful in attaining further knowledge from what I already have about the tools GIS has to offer*." The information provided in the GIS modules is helpful not just for students but it would be equally helpful for in-service professionals alike. One of the participants mentioned, "*I can see myself using these modules for further knowledge when I'm at work. Provided I have to use GIS for that problem and if there's are* [sic] *enough tasks to select from*"

3) GIS Review

One of the other things students mentioned about the GIS modules is the fact that they see these modules as video archives for GIS-related tasks. So, they think they always have the ability to come back to the site (www.learn-civil-gis.org) if they need specific information. Irrespective of whether they are students or in-service professionals, what time it is or where they are, they always have the ability to come back to the site and go through the specific information they want. One participant mentioned, "*When I'll be a working professional and I forgot a step at doing something in GIS, I'll definitively come back to the site and refresh my information*." Another mentioned, "*If I forget about how to use a particular tool within ArcGIS, I can go to the website and refresh myself in my leisure time.*"

CONCLUSION

In regard to the primary objective of this research, both the quantitative and qualitative analysis supported the effectiveness of the system. The statistical analysis indicated that students rated the laboratory as significantly more effective for learning and motivation in comparison to their textbook. In addition, students rated the laboratory exercise significantly more applicable to real world learning than their class lectures or the text. Furthermore, students rated their knowledge about the subject area significantly higher after the laboratory assignment than before. Qualitative analysis corroborated the quantitative finding in that the results indicated that the laboratory activity indeed enhanced the learning of core content along with improved motivation and enhanced spatial understanding.

The second goal of this research was to understand how the learning system fit within/contributes to learning. Open-coding analysis identified broad Overview of GIS, specific GIS Functions, and GIS review to be the prime reasons for using the GIS learning system. For the learning system to be effective, the above-mentioned factors should be taken into consideration. Students' comments suggest that the overall design of the learning system is effective.

The advantage of doing a qualitative study with grounded theory is that additional relevant data can be collected and analyzed to develop the grounded theory model, which will give us a more in-depth understanding of why and how students use the learning systems in GIS applications. Subsequent interviews can be carried out in the next laboratory sessions to refine a theory and to make sure that theoretical saturation has been reached. This theoretical model can then provide guidelines to educators in making decisions in implementing GIS in their respective curricula.

The adoption of GIS into the civil engineering curriculum is challenging due to the time required developing GIS learning objects and the effort required for educators to become familiar with these objects. Making GIS tasks fit in a 2-hour laboratory session, without increasing the number of laboratory sessions, for an already significantly full schedule is equally challenging. The system under consideration could potentially alleviate these logistical issues.

This research is still in progress. At this moment, GIS learning objects are being developed for surveying, water resources, transportation and environmental issues. Another set of data collection for the existing module is also being performed in the spring of 2009. Students' suggestions for improving the learning system are being implemented in the latest modules. Similar updates are being carried out in the existing material as well.

IMPLICATIONS AND LIMITATIONS

Previous to this study, a series of usability studies (Sullivan et al., 2005), and an initial in-class evaluation (Hall et al., 2005) of the Geotech/GIS module were carried out. During those stages the interface was modified a number of times. Given this, and the positive results of the current study, the interface has not been modified further.

However, these results have influenced the on-going project on learning systems for integrating GIS into Civil Engineering in two ways. First, a number of additional modules are being developed, to cover areas such as water resources, air quality, and traffic control. In all cases the initial designs are based on the GIS learning system, and this decision is supported by the present results. Second, our research will now include an examination of the learning system as a tool for review, and getting an overview of the GIS system, in addition to evaluation as a direct learning tool. Consequently, we are currently evaluating the effectiveness of the tool, when used outside a lab environment.

LIMITATIONS

A basic limitation of the present study was the lack of a control group, making it difficult to tell whether the increase in perceived knowledge was a result of time spent with the material, or the particular learning system. Moreover, there is no comparison, for example, between ratings of motivation for this learning system, vs. motivation ratings for another type of lab activity over the same materials. However, it should also be noted that an initial evaluation of the learning system carried out a few years ago, did include a control group, in which students payed an educational game as their lab activity. Interestingly, participants rated the game as more motivational, but scored significantly lower than those who used the learning system, on an objective quiz over the content studied in the lab (Hall et al., 2005).

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REFERENCES

1. Black, F. A., MacDonald, B. H., & Black, J. M. W. (1998). Geographic Information Systems: A New Research Method for Book History. *Book History,* 1(1), pp. 11-31.
2. Easa, S. M., Li, S., & Shi, Y. (1998). GIS Technology for Civil Engineering Education, *Journal of Professional issues in Engineering Education and Practice*, 124(2), pp.40-47.

3. ESRI. (2008). What is GIS. Environmental Systems Research Institute Website, Retrieved August 15, 2008 from http://www.gis.com/whatisgis/index.html
4. Fitzpatrick, C., & Maguire, D.J. (2001). GIS in schools: infrastructure, methodology and role. In Green, D.R. (Ed.) *GIS: A Sourcebook for Schools* (pp.62-72). London: Taylor & Francis.
5. Francica, J. (2000). Location analysis tools help Starbucks brew up new ideas. *Business Geographics,* 8(8), pp. 32-33.
6. Furner, J. M., & Ramirez, M. (1999). Making connections: Using GIS to integrate mathematics and science. *TechTrends-Journal of the Association for Educational Communications Technology,* 43(4).
7. 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-Learning Conference*, Montreal, CA, 1562-1565, *http://dl.aace.org/9618*
8. Hall, R.H., Luna, R., Hilgers, M.G., Sullivan, J.M., Lawrence, W.T., & Buechler, M.R. (2005). Evaluation of a Prototype GIS Learning System to Teach Civil Engineering Concepts. *Proceedings of the World Conference on Educational Multimedia, Hypermedia, & Telecommunications*, 3569-3574.
9. Hall, R.H., Stark, S., Hilgers, M., & Chang, P. (2004). A Comparison of Scaffolding Media in a Learning System for Teaching Web Development, *Proceedings of the AACE E-Learn Conference, pp. 1906-1913*, http://dl.aace.org/16707
10. Hall, R.H., Watkins, S.E., & Eller, V.E. (2003). A model of web based design for learning, in M. Moore and B. Anderson (Eds.) *The Handbook of Distance Education*. (pp. 367 – 376). Mahwah, NJ: Erlbaum.
11. Hockstra, D. & Mattejat, P. (2002). Manage drainage infrastructure. *Public Works,* 133(5), pp.170-171.
12. Johnson, L. (2003). Elusive Vision: Challenges Impeding the Learning Object Economy, *MacroMedia White Paper.*
13. Kerski, J. J. (2003). The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography 102*(3), pp. 128-137.
14. Lubenow, A. & Tolson, K. (2001). GIS technology helps pinpoint patients. *Health Management Technolog*y, 222*(*1), pp. 54-55.
15. Maguire, D. J. (1991). An overview and definition of GIS. In *Geographical Information Systems Principles and Applications*, edited by D. J. Maguire, M. F. Goodchild, and D. W. Rhind. *New York: Longman Scientific and Technical; John Wiley and Sons, Inc*., pp. 9-20.
16. Sarnoff, H. (2000). Census 1790: A GIS project. *Computers in the Social Studies* 8(1).
17. Star, J. & Estes, J. (1990). *Geographic Information Systems: An Introduction*. Englewood Cliffs, NJ: Prentice-Hall.
18. Sullivan, J.M., Hall, R.H., Hilgers, M.G., Luna, R., Lawrence, W.T., & Buechler, M.R. (2005). Iterative Usability Evaluation Methods Applied to Learning Technology Development. *Proceedings of the World Conference on Educational Multimedia, Hypermedia, & Telecommunications*, 1188 - 1193.
19. Tandon, B., Hall, R., Luna, R., Sheng, H. & Boese, M. (2008). Integration of a GIS Learning Management System into Civil Engineering Curricula: An Evaluation. In G. Richards (Ed.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2008* (pp. 497-505). Chesapeake, VA: AACE.