

Chapter XVIII

An eLearning Portal to Teach Geographic Information Sciences

S. Grunwald

University of Florida, USA

B. Hoover

University of Florida, USA

G.L. Bruland

University of Hawai'i Mānoa, USA

ABSTRACT

In this chapter the authors describe the implementation of an emerging virtual learning environment to teach GIS and spatial sciences to distance education graduate students. They discuss the benefits and constraints of our mixed architecture with the main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment entailed the following: (i) Facilitating student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools; (ii) Developing an interactive online learning environment in which students have access to a suite of passive and active multi-media tools; and (iii) Allowing student access to a mixed web-facilitated / hybrid architecture that stimulates their cognitive geographic skills and provides hands-on experience in using GIS.

INTRODUCTION

Geographic information systems (GIS) are a rapidly evolving technology that is integrated in

mainstream undergraduate and graduate curricula. Spatial sciences and GIS are multidisciplinary in nature and have important relevance beyond their traditional disciplinary homes. Currently,

Spatial sciences and GIS courses are offered through geography, civil engineering, geomatics, soil, water and environmental science and other programs. A GIS is a computer-based system for managing, storing, analyzing, and presenting spatial data. GIS have three important components – computer hardware, sets of application software modules, and a proper organizational context including skilled people (Burrough and McDonnell, 1998). As such, the GIS curriculum is particularly suited to the development of innovative learning models adaptable to students from different disciplinary backgrounds. GIS courses and programs are also ideally suited to use novel technologies as the discipline itself is technologically enabled, or even technologically driven. Zerger et al. (2002) pointed out that it is important to infuse spatial science theory with practical examples / assignments and projects to optimize learning outcomes. Thus, transforming on-campus GIS courses into a virtual learning environment requires maintaining both lecture and lab components. Spatial sciences aim to stimulate cognitive geographic thinking skills that involve solving geospatial problems, to comprehend and integrate huge amounts of geospatial data, and to facilitate understanding of both large-scale and small-scale geographic features of ecosystems. These cognitive geographic skills are a prerequisite to understanding the underlying mechanisms for spatially-explicit modeling using GIS software. Hands-on GIS assignments and projects facilitate student learning about GIS functionality and help them build their own spatial models.

Distance education courses and programs have adopted a variety of multimedia and Internet technologies. Recent changes in information technology have challenged instructors not only in terms of *what* they teach, but also *which* technology they use to teach. The proliferation of web-based and interactive multimedia technologies that are used to teach spatial sciences has transformed numerous on-campus courses into web-facilitated, hybrid (blended) and distance education

courses. Hybrid courses mix traditional face-to-face instruction with a substantial portion that is delivered online. Virtual learning environments are diverse, ranging from simple web-pages to complex hard- and software solutions. A virtual learning environment is a set of teaching and learning tools designed to enhance a student's learning experience by including computers and the Internet in the learning process. Criteria to distinguish virtual learning environments include: (i) delivery type - audio, video-based systems (e.g. Power Point slides, videoclips, compressed interactive video, virtual reality worlds, and others); (ii) delivery media (e.g. books, journal articles, CD, DVD, Internet); (iii) communication type (synchronous and asynchronous) and student involvement – (active and passive); (iv) level of abstraction – content (e.g. text, maps, 3D models, 4D simulations, interactive virtual models); (v) presence of the instructor (e.g. availability and accessibility of instructor by students); (vi) level of interactivity between students, instructor and computerized entities (student-student-, student-, student-instructor-, instructor-, and student-computer centered); and (vii) user access (local e.g. physical lab or field trip that requires the presence of a student at a particular geographic place or remote e.g. Internet-based access or simulated/emulated equipment and instruments). Virtual environments present a multimedia library of shapes, landscapes and sounds that establish a system for construction and symbolic transformation. The virtual environment as projective construction provides an opportunity for participants to collaborate in a variety of multisensory interactions: visual-spatial, audio-spatial, and kinesthetic.

EXISTING GIS LEARNING SYSTEMS

Student-instructor interaction including face-to-face interaction and hybrid settings where students interact with an instructor using synchronous (e.g. interactive video, chatroom) or asynchronous (e.g.

message board, email) communication tools are commonly used to teach spatial sciences courses. Other virtual learning environments for GIS and spatial sciences focus on student-centered, self-paced instruction. For example, virtual GIS classrooms are offered through the Environmental Systems Research Institute (ESRI) virtual campus for GIS learning (<http://campus.esri.com>) and the UNIGIS program (<http://www.unigis.org>). These initiatives are not interactive, instead they simply deliver existing curricula via a hyperlinked Internet delivery mechanism. Students have to provide their own GIS software to take these courses. Other disadvantages include that no tutors or instructors are available for students. Students receive support only through online message boards that may not be able to replace an interactive synchronous learning environment. Other implementations use webGIS and virtual GIS tools which are student-computer centered. Peng and Tsou (2003) define webGIS as a GIS distributed across a computer network to integrate, disseminate, and communicate geographic information on the WWW (Peng and Tsou, 2003). Wright et al. (2003) discussed implications of a webGIS, a computational environment and toolset that provides scientists and educators with simultaneous access to data, maps and query wizards. They stress that webGIS is only a preliminary step rather than a final solution to teach GIS since spatial data must be also linked to models for better exploration of new relations between observed values, refinement of numeric simulations, and the quantitative evaluation of scientific hypotheses. ArcIMS software developed by ESRI has been used in numerous applications to develop webGIS (Wright et al., 2003; Mathiyalagan et al., 2005), however, it has limited capabilities to teach GIS in a virtual learning environment. Other open source GIS tools have been developed to support teaching. For example, Stainfield et al. (2000) presented a Java/VRML standalone multidimensional interface explorer with basic GIS functionality. Though such tools

provide display and query capabilities for spatial datasets they fall short in GIS instruction due to limited functionality for spatial modeling.

MOTIVATION AND GOALS

Sui and Bednarz (1999) stress the need for student-instructor interaction in geographic education especially when considering the inherent multiple intelligences possessed by each individual. In other words, students have varying learning needs and hence they respond differently to different delivery models. Figure 1 summarizes student-instructor-computer interaction that varies from passive to active engagement using a variety of delivery media. Barraclough and Guymer (1998) and Fisher and Unwin (2002) argued that interactivity enhances the perception and interpretation of spatial datasets (e.g. environmental systems). Deadman et al. (2000) used a multimedia approach to teach GIS interactively using a high-resolution, computer-based classroom for delivering lecture-based live presentations of the GIS software. Their hardware configuration provided high-speed, high-quality video linkages to broadcast GIS demos to distance education students at remote sites.

The architecture of virtual learning environments to teach GIS and spatial sciences range from centralized, closed systems to complex distributed open systems (Figure 2a to 2e). Systems differ in respect to the access to spatial datasets that (i) can be hosted on a desktop computer, (ii) a computerized entity that provides data a/o map services, (iii) a server or (iv) nodes that are part of a distributed open system (Pseng and Tsou, 2003). Likewise different architectures facilitate different access to GIS software. For example, in a centralized, closed system the GIS software (e.g. ArcGIS, IDRISI) is installed on a desktop machine. Web-facilitated instruction provides limited GIS functionality through the Internet

Figure 1. Pyramid of delivery types of content to teach GIS and spatial sciences courses

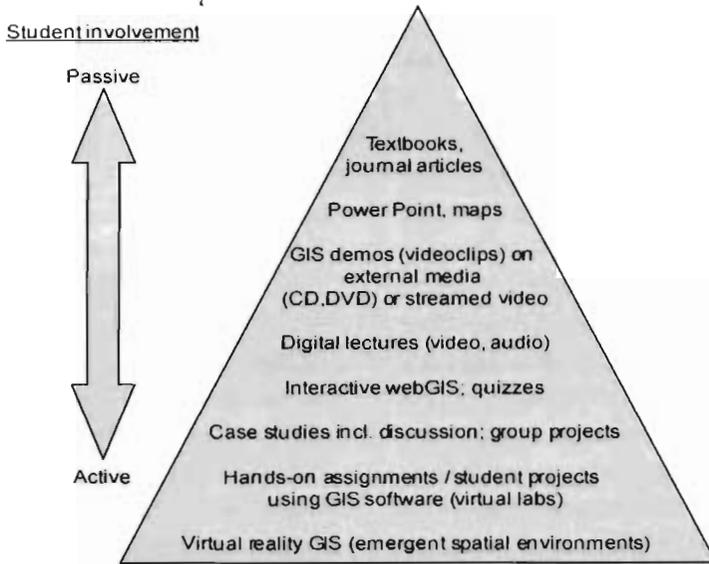
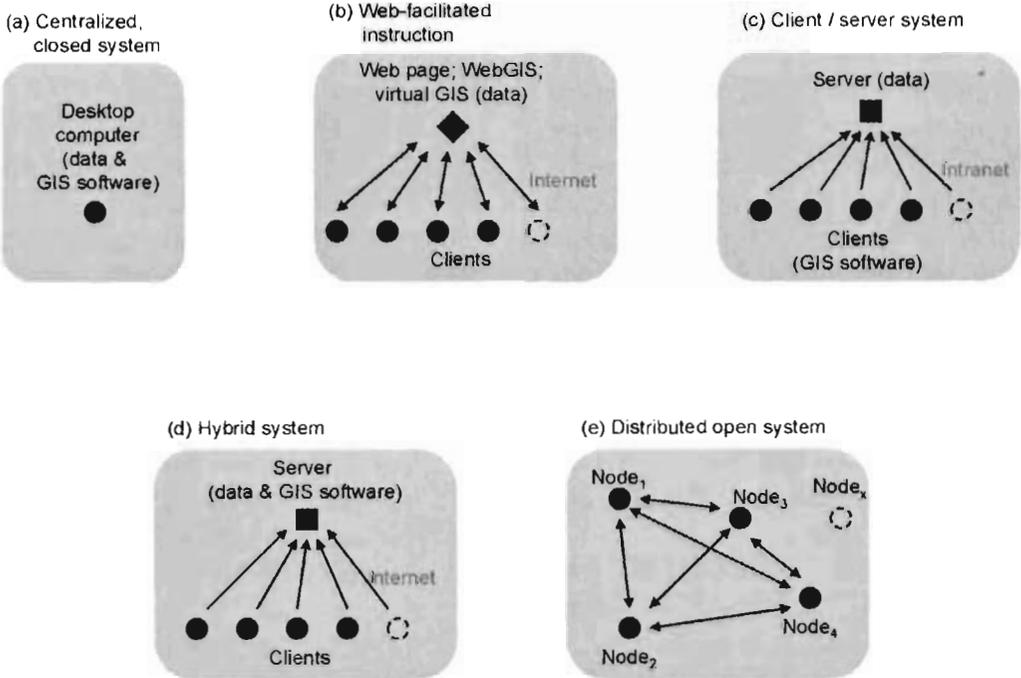


Figure 2. Architectures to teach GIS and spatial sciences courses



while client/server systems require that the GIS software is installed on all client machines. The latter architecture has been used extensively to teach GIS and spatial sciences courses at the University of Florida (UF) and elsewhere. At many universities, site licenses for expensive GIS software packages are available that do not extend to off-campus use, therefore favoring on-campus client/server systems. An emerging architecture that uses a hybrid setup in which the GIS software is installed only on the server eliminates the need for clients to install expensive software on their machines. Clients access the spatial data and GIS software through the Internet providing complete independence from a geographic location. Advantages of a hybrid system include flexible 24/7 access of clients to the server and fast performance of complex spatial operations on the server machine. Hybrid systems provide a collaborative virtual learning environment that is shared by students and the instructor. Other possible architectures are based on a distributed open system where each node can become a client or a server based on the task (Pseng and Tsou, 2003).

In this chapter we describe the implementation of an emerging virtual learning environment to teach GIS and spatial sciences to distance education graduate students. We discuss the benefits and constraints of our mixed architecture with main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment entailed:

- a. To provide student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools,
- b. To develop a liberal online learning environment in which students have access to a suite of passive and active multi-media tools,
- c. To provide students access to a mixed web-facilitated / hybrid architecture that

stimulates their cognitive geographic skills and provides hands-on experience in using GIS.

The virtual learning environment was utilized to teach GIS and spatial sciences in context of land resource management for distance education graduate students enrolled in the Distance Education Graduate Track in Environmental Science offered through the Institute of Food and Agriculture Sciences (IFAS), UF [<http://soils.ifas.ufl.edu/distance/>]. The course is an elective in the GIS certificate program coordinated by the Interdisciplinary Concentration in GIS. The course is also open to non-degree seeking distance education students interested in GIS and spatial sciences. Thus, the science background of students enrolled in this course is diverse and multi-cultural.

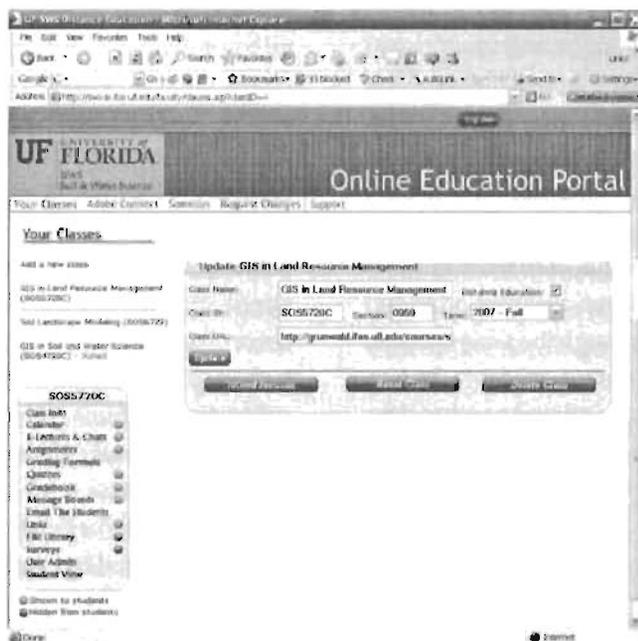
IMPLEMENTATION

Development of Virtual Learning Entities

We adopted a multi-tier approach to develop virtual entities that provided students access to core content, communication- and service tools, and a collaborative virtual study environments. These tools aimed to train students in spatial sciences theory. An online education portal provided access to a variety of learning tools (Fig. 3). The following list provides an overview:

1. **Development of core content tools:** The core tools provided course learning content to students including the following media: (a) reading material in form of Adobe pdf format; (b) Power Point slides narrated with lecture notes; (c) digital lectures recorded in Adobe Connect; (d) Flash animations; (e) quizzes; (f) library of ArcGIS video clips (step-by-step instructions to explain spatial

Figure 3. Snapshot of the online education portal that facilitates access to learning tools



functionality of ArcGIS software); and (g) hyperlinks to access Internet resources on GIS. Almost all of these tools, except for quizzes, are student-centered and focus on information delivery.

Communication tools: We provided students with a variety of communication tools that aimed to engage students in exchange of information, reflection, and discussion. A mix of synchronous and asynchronous communication tools were used to accommodate students' diverse preferences to interact with the instructor and teaching assistants. Our tools included: (a) message board; (b) chatrooms facilitated by Adobe Connect; (c) bulk emails (shared with all students); (d) self-reflective emails (shared between students and the instructor); and (e) phone.

Service tools: The online education portal contains a variety of service tools that guided students through the course including: (a) calendar; (b) check list that listed all required

tasks (e.g. reading assignments, lectures, GIS assignments, etc.); (d) grading tool; (e) event viewer that listed all important class events; and (f) upload and download functions for course material, assignment reports and a final project.

4. **Tools/methods that stimulated collaborative work:** To engage students in discussions numerous techniques were used: (a) focus questions for chat sessions; (b) provocative comments posted by instructor and teaching assistants on the message board; (c) student-corner that provided photographs, profiles and contact information for all students in class; and (d) student peer-evaluation of GIS projects.

Implementation of the Virtual GIS Computer Laboratory

The lab component of the GIS course required the solving of traditional and topical GIS problems and aimed at stimulating higher order problem solving

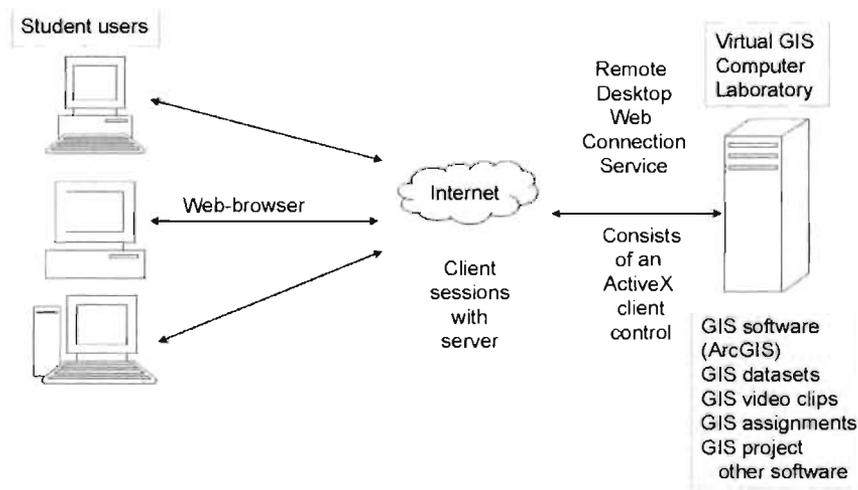
skills using real-world spatial datasets. Each of the GIS assignments addressed one specific GIS topic (e.g. map projections, raster-based operations) using real-world GIS datasets and focused on specific land resource issues (e.g. land use change analysis, carbon sequestration, characterization of the spatial distribution and variability of total soil phosphorus in a wetland ecosystem). Detailed step-by-step instructions supported by snapshots of the GIS-based spatial operations were provided to students to guide them through the assignments. At the end of each assignment students had to answer 2-4 questions closely related to what they just learned. To answer these questions, students employed their GIS knowledge to solve problems with new datasets.

We adopted a hybrid virtual architecture that provided distance education students access to the ArcGIS 9.1 software and spatial datasets to conduct the GIS assignments and to work on an independent and/or group project. Figure 4 shows the architecture of our virtual GIS computer laboratory. Currently up to about 250 students can work simultaneously in the virtual computer lab. The only limitations to this system are hard drive space and memory. Students access the virtual

computer lab using a Windows terminal server application through a web browser. The virtual GIS computer lab uses the Remote Desktop Web Connection service provided by the Windows XP Professional operating system. Remote Desktop Web Connection consists of an ActiveX client control and sample web pages. ActiveX controls are reusable software components that can quickly add specialized functionality to web sites, desktop applications, and development tools. ActiveX controls are used for developing programmable software components used in a variety of different software tools. The ActiveX client control provides virtually the same functionality as the full Remote Desktop Connection client, but it is designed to deliver this functionality over the Web. When embedded in a web page, the ActiveX client control can host a client session with a server, even if the full Remote Desktop Connection client is not installed on a user's computer. In essence, the Remote Desktop Web Connection allows students to access a remote computer (server), via the Internet, from a local machine using a web browser.

Using Microsoft Remote Desktop as a group appliance has had several drawbacks in practical

Figure 4. Architecture of the Virtual GIS Computer Laboratory



use. The first of which is the lack of upgradeability. Servers were built to handle network traffic and file sharing, but not for multiple users logged in simultaneously. The second constraint is related to usage because the speed of Remote Desktop applications decreases as the number of users increases given a fixed set of hardware configuration (i.e., processor speed and memory). Virtual Desktops, which are essentially an image of a computer, take a whole new approach for shared computing. They are hosted from a Storage Area Network (SAN), which is essentially a group of computers that share the same storage, processors and memory. The software on the SAN will read this image and allow you to connect to it as if it were an independent computer. The SAN is able to maintain a large number of desktops without compromising usability. The software manages the virtual desktops by having a single image of a computer and simply making copies of it for multiple users. The advantages of using a Virtual Desktop Machine over a Remote Desktop server are numerous. All user data is saved to a shared storage area, so if a desktop begins to show problems, it can be deleted and a new desktop can be created in its place at the touch of a button. Also, software management is simplified by only having to maintain one computer. All the Virtual Desktop Machines are copied from the single image. In addition, the Virtual Desktop Model is much more cost effective and flexible from an IT standpoint.

The virtual GIS computer lab differs from Learning Management Systems (i.e. Blackboard or WebCT Vista), and chat software such (i.e. Adobe Connect or Elluminate) in that it provides access to expensive software (i.e. ArcGIS), spatial datasets and public and private workspace (files and folders) on the server. In addition, the virtual lab provides a secure learning environment that enables students to learn complex, multi-step geospatial operations.

Constraints and Benefits

Our versatile virtual learning entities provided students with core content and service tools that were used extensively by students throughout the course. A survey conducted in 2003 and 2004 in which 27 distance education students replied (out of 34 enrolled students) ranked the GIS assignments conducted in the virtual computer laboratory highest (4.7) followed by Power Point slides (3.6), reading material (3.6), digital lectures (3.5), ArcGIS video clips (3.3), quizzes (3.0) and hyperlinks (3.0), on a Likert scale ranging from "5 = extremely useful" to "0 = not useful at all". While some students have text or visual learning styles, others have auditory learning styles. Thus, we used a variety of contextualizations for virtual entities customized for different learners. For example, the same learning material about one specific topic was provided in form of reading material, Power Point slides, a Flash animation and a digital movie to reach students with different learning styles. Such a liberal virtual learning environment gives students freedom to focus on those media/tools they respond to best. Gardner (1983) asserts that humans learn through many different cognitive styles ranging from bodily-kinesthetic, interpersonal, intrapersonal, linguistic, logical-mathematical, musical and spatial. This suggests that the most effective instructional media should engage multiple types of learning styles. Zerger et al. (2002) argued for a self-learning multimedia approach for enriching GIS education. Such a student-centered approach is liberal in the sense that students make choices when, how much, and what to learn. They do caution, however, that self-learning modules are designed to complement rather than replace existing traditional approaches in the classroom. Marion and Hacking (1998) examined the relative merits of the Internet in education and argued that the evolution of the Internet provides the opportunity to build a more constructivist learning environment. We agree that a virtual approach

Public folders in the virtual GIS computer laboratory provided access to spatial datasets and assignments and generic folders were shared by all students, teaching assistants and the instructor (Fig. 4). We constrained the access (read, write, execute permissions) to individual (private) student folders (Fig. 4). This method did not permit the students to share their GIS output from assignments with each other, which reduced the risk of plagiarism. The teaching assistants and the instructor had unconstrained administrator access to all files and folders in the virtual GIS computer laboratory. This is important for troubleshooting and providing student support in real-time for complex spatial operations. Because the virtual GIS computer laboratory is a collaborative learning environment, the students and instructors were able to share the same view of GIS files and projects simultaneously. This facilitated collaborative student-student and student-instructor interactions independent from a geographic location.

The Remote Desktop Web Connection provided a high-encryption ensuring security to the server. Remote Desktop works well over the Internet, because only the keyboard input, mouse input, and display output data are transmitted over the network to a remote location. However, to ensure optimized viewing of maps and graphics, a high-speed Internet connection between the client and server machine provided the best solution. A benefit of the Remote Desktop set-up was that client computers shared a clipboard that allowed data to be interchanged. Sala (2003) described similar examples of hypermedia modules for distance education and virtual universities that provide interactivity for learning while many other learning tools are still limited to display data and instructional material. For example Hays et al. (2000) presented a tool that was limited to display earth science data. In contrast, Barak and Nater (2002) developed a web-based fully-interactive learning environment to introduce

students to minerals and molecules. Thai and Upchurch (2002) presented a synchronous experimental machine-vision virtual laboratory to engage students in hands-on assignments. Almost all authors emphasize two critical elements that engage students in learning activities namely “interactivity” and “hands-on tools”.

While most students felt comfortable performing tasks in the virtual GIS computer laboratory others were challenged by the highly-interactive computerized online environment. Overall, 3.6% of students found that it was very easy, 24% found it easy, 17.4% somewhat easy, 27.6% moderately easy, 16.9% difficult, and 10.5% found it very difficult to perform tasks in the virtual GIS computer lab.

A complete overview of the survey can be found in Grunwald et al. (2005). The response time of numerical geospatial operations conducted in the virtual GIS computer laboratory was no different than the same operations conducted on a local PC. When asked if the GIS technology used in this course improved the learning outcomes, students unanimously answered “Yes.” The assessment of student interaction included the following responses: (i) 100% of students used the virtual GIS lab (no drop outs); (ii) on average, 85% of students submitted biweekly self-reflective emails throughout the course; (iii) the instructor received about 2-3 emails daily from distance education students; (iv) email traffic was generally higher in the evening hours and weekends; and (v) on average, 650 messages were posted on the message board in a given semester.

Five years of teaching in distance education mode has enabled us to identify some limitations with the current virtual GIS computer lab design. To ensure fast display a high-speed Internet access is required. Though broadband availability is greatly expanding in the U.S., it poses limitations to students at remote locations in developing countries. In our course students from 5 different U.S. states and from South America were enrolled

to receive advanced instruction in spatial sciences and GIS that was previously unavailable. At lower bandwidths the display of large, complex maps slows down. The hard drive and memory of the server machine needs to be designed for peak usage (e.g. simultaneous work in the virtual GIS computer laboratory before assignment and project deadlines). Other limitations included a major time commitment to develop the virtual learning environment that required content development, programming and extensive testing. Despite some of the limitations mentioned above, our virtual learning environment has greatly improved GIS and spatial sciences instruction at the University of Florida.

CONCLUSION

Our innovative architecture for the virtual GIS computer laboratory is simple, affordable and versatile in design. It provides a flexible, collaborative virtual learning environment for distance education instruction. A hybrid approach was used to complement virtual entities of core content, service and communication tools with a virtual GIS computer laboratory. The overall response from students using the virtual GIS computer laboratory was overwhelmingly positive. Some students, that were less computer-literate, indicated that it was somewhat difficult for them to perform tasks in the virtual computer laboratory. Instructors and teaching assistants noted that the virtual learning concept facilitated to oversee students work and interact with students. Despite our positive experience with our virtual learning environment, we caution that a balanced team of members from different disciplines is required for successful implementation. Our team comprised two faculty members teaching GIS and spatial sciences, a computer programmer and network specialist.

Although the virtual computer laboratory was designed for one specific GIS / spatial sciences

course, it has the potential to be instrumental in courses that make use of software packages a/o simulation models (e.g. hydrologic and water quality simulation models, statistical software). The virtual computer lab concept has also been adopted by IFAS at UF to teach on-campus computer-mediated courses. This indicates that emerging technologies do not only improve distance education instruction but also on-campus courses that might eventually develop into blended/hybrid or online courses.

ACKNOWLEDGMENT

We would like to thank graduate student V. Ramasundaram who developed the Java-based tools for the graduate distance education course in GIS. These tools were integrated into the online eLearning portal by B. Hoover. D. Jesseman helped to implement a pilot remote desktop application in support of the GIS course in Land Resource Management. We would also like to acknowledge the contributions of distance education teaching assistants K.A. McKee, R.G. Rivero, G.M. Vasques and J. McKay.

REFERENCES

- Barak, P., & Nater, E. (2004). *The virtual museum of minerals and molecules*. Available at: http://www.soils.wisc.edu/virtual_museum/index.html (verified March 23, 2006).
- Barracough, A., & Guymer, I. (1998). Virtual reality - a role in environmental engineering education? *Water Sci. Tech.*, 38(11), 303-310.
- Burrough, P. A., & McDonnell, R. A. (1998). *Principles of Geographical information Systems – Spatial Information Systems and Geostatistics*. Oxford, UK: Oxford University Press.
- Deadman, P., Hall, G. B., Bain, T., Elliot, L., & Dudycha, D. (2000). Interactive GIS instruction

using a multimedia classroom. *J. of Geography in Higher Education*, 24(3), 365-381.

Fisher, P., & Unwin, D. (2002). *Virtual Reality in Geography*. New York: Taylor & Francis.

Gardner, H. (1983). *Frames of Mind*. New York: Basic Books.

Grunwald S., Ramasundaram, V., & Jesseman, D. K. (2005). A modular e-learning environment to teach GIS to on-campus and distance education students. *North American Colleges, Teachers of Agriculture J.* 49(1), 6-13.

Hardwick, S. (2000). Humanising the technology landscape through collaborative pedagogy. *J. of Geography in Higher Education*, 24(1), 123-129.

Hays, J. D., Phirman, S., Blumenthal, B., Kastens, K., & Menke, W. (2000). Earth science instruction with digital data. *Computers & Geosciences*, 26, 657-668.

Marion, A., & Hacking, E. H. (1998). Educational publishing and the World Wide Web. *J. of Interactive Media in Education*, 98(2). Available at: <http://www-jime.open.ac.uk/> (verified March 23, 2006).

Mathiyalagan, V., Grunwald, S., Reddy, K. R., & Bloom, S. A. (2005). A webGIS and geodatabase for Florida's wetlands. *Computers and Electronics in Agriculture*, 47, 69-75.

Peng, Z. R., & Tsou, M. H. (2003). *Internet GIS – Distributed Geographic Information Services for the Internet and Wireless Networks*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Sala, N. (2003). Hypermedia modules for distance education and virtual university: some examples. *J. of Distance Education Technologies*, 1(1), 78-95.

Stainfield, J., Fisher, P., & Ford, B. (2000). International virtual field trips: a new direction? *J. of Geography in Higher Education*, 24(2), 255-263.

Sui, D. Z., & Bednarz, R. S. (1999). The message is the medium: geographic education in the age of the Internet. *J. of Geography*, 98, 93-99.

Thai, C. N., & Upchurch, B. L. (2002). *Synchronous experimentation via web access to laboratories*. ASAE Meeting, Chicago, Illinois, July 28-31. Paper No. 023024.

Wright, D. J., O'Dea, E., Cusing, J. B., Cuny, J. E., & Toomey, D. R. (2003). Why webGIS map not be enough: a case study with the Virtual Research Vessel. *Marine Geodesy*, 26, 73-86.

Zerger, A., Bishop, I. D., Escobar, F., & Hunter, G. J. (2002). A self-learning multimedia approach for enriching GIS education. *J. of Geography in Higher Education*, 26(1), 67-80.