

# Expanding Distance Education in the Spatial Sciences Through Virtual Learning Entities and a Virtual GIS Computer Laboratory

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## ABSTRACT

*In this paper 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 the main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment included: (i) Facilitating student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools; (ii) Developing a liberal 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.*

*Keywords: geographic information system; virtual learning; Web classroom*

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## 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 & 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, Bishop, Escobar, and Hunter (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: (1) delivery type—audio, video-based systems (e.g., Power Point slides, videoclips, compressed interactive video, virtual reality worlds, and others); (2) delivery media (e.g., books, journal articles, CD, DVD, Internet); (3) communication type (synchronous and asynchronous) and student involvement (active and passive); (4) level of abstraction and content (e.g., text, maps, 3D models, 4D simulations, interactive virtual models);

(5) presence of the instructor (e.g., availability and accessibility of instructor by students); (6) level of interactivity between students, instructor, and computerized entities (student-student, student, student-instructor, instructor, and student-computer centered); and (7) 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, e-mail) 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 learn-

ing (<http://campus.esri.com>) and the UNIGIS program (<http://www.unigis.org>). These initiatives are not interactive, but instead 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 web GIS 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 World Wide Web (Peng & Tsou, 2003). Wright, O'Dea, Cusing, Cuny, and Toomey (2003) discussed implications of a webGIS, a computational environment and toolset that provides marine 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, Grunwald, Reddy, & Bloom, 2005), however, it

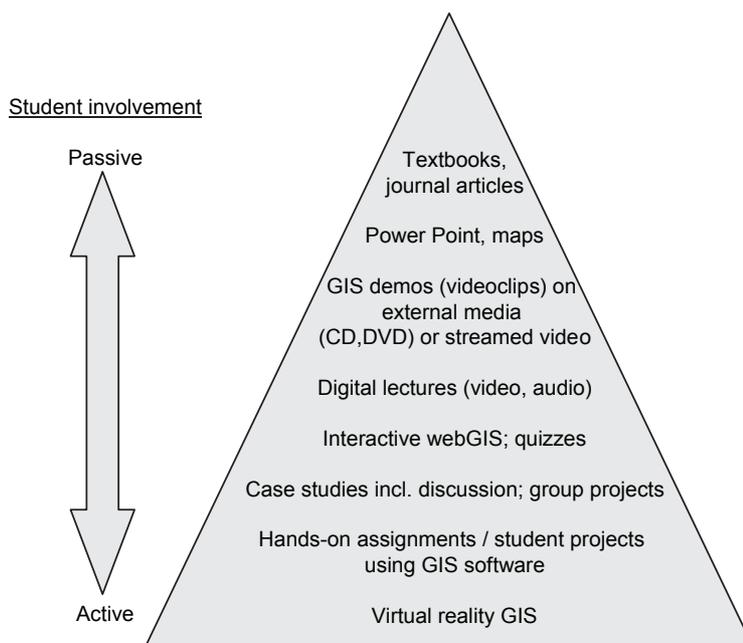
has limited capabilities to teach GIS in a virtual learning environment. Other open source GIS tools have been developed to support teaching. For example, Stainfield, Fisher, and Ford (2000) presented a Java/VRML stand-alone, multidimensional interface explorer with basic GIS functionality. Though such 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, Hall, Bain, Elliot, and Dudycha (2000) used a multimedia approach to teach GIS interactively using a high-resolution, computer-based

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

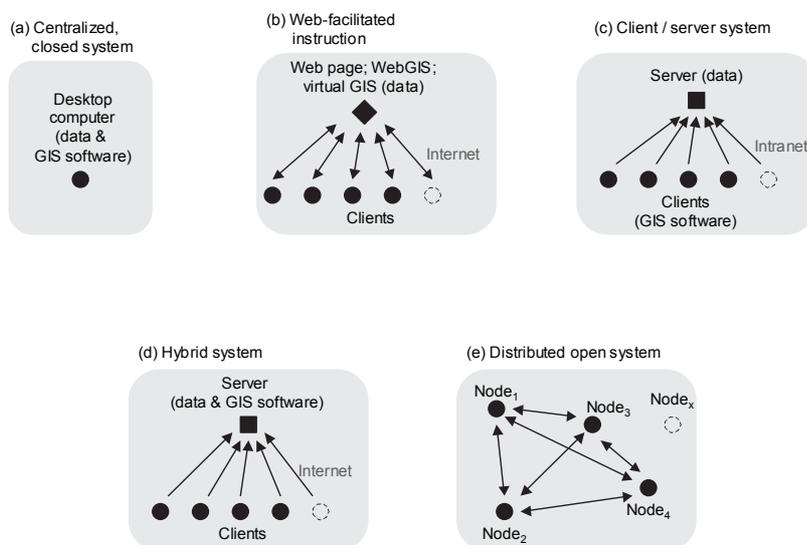


classroom for delivering lecture-based live presentations of the GIS software. Their hardware configuration provided high-speed, high-quality video linkages to broadcast GIS demos to distance education students at remote sites.

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 (1) can be hosted on a desktop computer, (2) a computerized entity that provides data and/or map services, (3) a server, or (4) nodes that are part of a distributed open system (Pseng & 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 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

Figure 2. Architectures to teach GIS and spatial sciences courses



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 & Tsou, 2003).

In this paper 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 included:

- 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 multicultural.

## **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. All tools were developed using Java, Active Server Pages, and HyperText Markup Language. These tools aimed to train students in spatial sciences theory. The following list provides an overview:

1. Development of core content tools:  
The core tools provided course

content to students including the following media: (a) reading material in the form of Adobe pdf format; (b) Power Point slides narrated with lecture notes; (c) digital lectures streamed in RealTime format; (d) Flash animations; (e) quizzes; (f) library of ArcGIS video clips (step-by-step instructions to explain spatial functionality of ArcGIS software); and (g) hyperlinks to access Internet resources on GIS. Almost all of these tools, except for quizzes, are student-centered focusing on information delivery.

## 2. 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; (c) bulk e-mails (shared with all students); (d) self-reflective e-mails (shared between students and the instructor); and (e) phone.

## 3. Service tools:

We developed a variety of service tools in Java that guided students through the course including: (a) calendar; (b) checklist that listed all required tasks (e.g., reading assignments, lectures, GIS as-

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

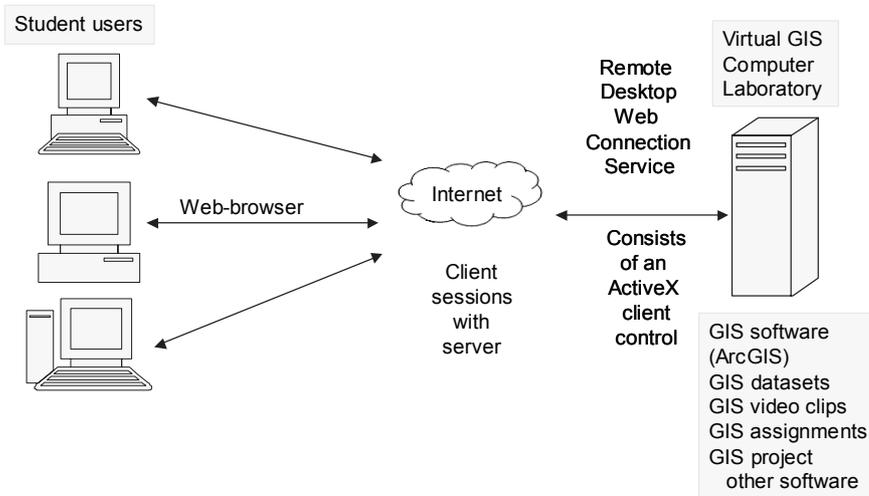
## 4. Tools/methods that stimulated collaborative work:

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 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

Figure 3. Architecture of the Virtual GIS Computer Laboratory



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 8.3 software and spatial datasets to conduct the GIS assignments and to work on an independent and/or group project. Figure 3 shows the architecture of our virtual GIS computer laboratory. The hardware components included a Dell PowerEdge 6450/700 model with 4 x Genuine Intel 699 MHz processors, 4 x 73 GB hard drives, 4 GB physical RAM, and total virtual memory of ~ 3 GB (adjustable based on user behavior). Currently, up to about 40 students can work simul-

taneously 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 2003 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 Web 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. When a student accesses a Web page that contains the embedded Remote Desktop Web Connection ActiveX Client Control, the following sequence of events occurs:

- a. A Web browser such as Internet Explorer (IE), version 5 or later, downloads a configuration file (.cab), the ActiveX component (if not already present on the machine), that contains information which is required by the client to connect to the server (= the virtual GIS computer lab) via <http://itns.ifas.ufl.edu/tsweb/>.
- b. This file is downloaded only if: (1) the computer that accessed the Web page does not have an installation of the full Remote Desktop Web Connection program, or (2) the installed version of the .cab file on the client computer is older than the version on the Web page.
- c. After downloading, IE decompresses the .cab file and installs the ActiveX Client Control in IE's default location for downloaded controls on the target computer.
- d. The default connection page appears, asking the student for server, logon, and connection information. A password protection is build into our system to prevent access from nonregistered students.
- e. The Remote Desktop opens in the Web page. Depending on the acceptance of the password and the settings of the remote computer to which the student is trying to connect, the Windows logon screen appears.
- f. After the student logs successfully into the virtual GIS computer lab using the Remote Desktop Web Connection the student can start performing tasks (e.g., open the ArcGIS software to work on assignments). The student's requests are sent to the server as keyboard strokes and mouse events. These requests are processed by the server and the response is sent back to the student.

The virtual GIS computer lab differs from Learning Management Systems such as Blackboard or WebCT, and chat software such as Netmeeting in that it provides access to expensive software (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, multistep 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 scale ranging from "5 = extremely useful" to "0 = not useful at all." While some students have textual 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 the 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 as to 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 to learning GIS and spatial sciences is important because these disciplines evolve rapidly and textbooks are often outdated within a short amount of time. Our core content tools can be easily updated because they are organized in form of learning objects using a hierarchic setup.

We also promoted a flexible approach to interacting with students. While some students extensively used the public message board and chatroom sessions, other students preferred to communicate with the instructor on a one-to-one basis using self-reflective e-mails and phone conversations. Students were highly motivated to participate in group activities fostered through the virtual learning environment. They were encouraged to become involved in a peer-evaluation of their classmates GIS projects. Almost all students participated in this process. Hardwick (2000) notes that shifts towards collaborative models remove the common competitive paradigm inherent in education.

Since students only needed the Internet to access the virtual GIS com-

puter laboratory, no physical presence on-campus was required. Such an implementation is ideal to teach GIS and spatial sciences to distance education students that were traveling and/or engaged in other professional activities during the duration of the course. A major advantage was that students, teaching assistants, and the instructor had 24/7 access to the virtual GIS computer laboratory. Complex spatial GIS operations could be performed with the same speed in the virtual GIS computer laboratory when compared to local computers. In addition, students were not required to purchase and install expensive GIS software on their local client machines. Other benefits included a reduction of the need to download and upload large GIS files because almost all such data files needed for the assignments were made available on a public folder in the virtual GIS computer laboratory. For the GIS project, students were able to use a Web browser to download spatial datasets into their individual folders in the virtual GIS computer laboratory.

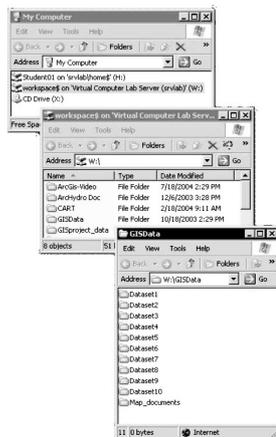
Public folders in the virtual GIS computer laboratory provided access to spatial datasets and assignments and generic folders were shared by all students, teaching assistants, and the instructor (Figure 4). We constrained the access (read, write, execute permissions) to individual (private) student folders (Figure 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 instruc-

tor 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.

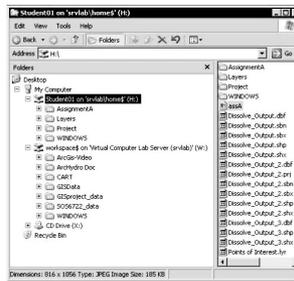
The Remote Desktop Web Connection provided a high –encryption, ensuring security to the server. Remote Desktop works well even over low bandwidth Internet connections, because only the keyboard input, mouse input, and display output data are transmitted over the network to a remote location. However, 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 setup 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, Phirman, Blumenthal, Kastens, and Menke (2000) presented a tool that was limited to displaying earth science data. In contrast, Barak and Nater (2002)

Figure 4. Student view of public and private files in the virtual GIS computer

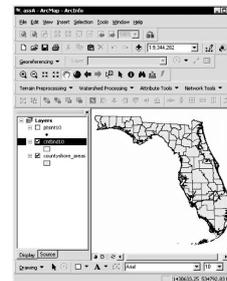
(a) Public GIS data and folders shared with all students in class



(b) Individual (private) student files



(c) Students and instructor share the same working environment



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, Ramasundaram, and Jesseman (2005). The response time of numerical geospatial operations conducted in the virtual GIS computer laboratory was no different from the same operations conducted on a local PC using 512 MB memory. 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: (1) 100% of students used the virtual GIS lab (no drop outs); (2) on average, 85% of students submitted biweekly self-reflective e-mails throughout the

course; (3) the instructor received about 2-3 e-mails daily from distance education students; (4) e-mail traffic was generally higher in the evening hours and weekends; and (5) on average, 650 messages were posted on the message board in a given semester.

Two years of teaching experience has identified some limitations with the current virtual GIS computer lab design. To ensure fast display, high-speed Internet access is required. Though broadband availability is greatly expanding in the US, it poses limitations to students at remote locations in underdeveloped countries. In our course students from five different US 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 peek usage (e.g., simultaneous work in the virtual GIS computer laboratory before assignment and project deadlines). Other limitations included a major time commitment to developing 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.

## CONCLUSIONS

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, who were less computer-literate, indicated that it was 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 a faculty teaching GIS and spatial sciences, a computer programmer, and a network specialist.

Although the virtual computer laboratory was designed for one specific GIS and spatial sciences course, it has the potential to be instrumental in courses that make use of software packages and/or 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 dis-

tance education instruction, but also on-campus courses that might eventually develop into blended/hybrid or online courses.

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