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Interactive GIS Instruction Using a Multimedia Classroom

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ABSTRACT *This paper discusses the design, development and use of a multimedia classroom for the instruction of undergraduate courses in Geographic Information Systems (GIS) at the University of Waterloo. The classroom, which seats 50 students, was custom-designed and co-developed by the School of Accounting, Faculty of Arts and the Mapping, Analysis and Design Unit of the Faculty of Environmental Studies (FES), with input from other groups on campus. The FES uses the room to teach 'hands-on' undergraduate GIS courses, ranging from introductory coverage of GIS technology use to advanced courses dealing with GIS application design and development. Instruction is facilitated by use of a high-resolution, large-screen video display connected to a networked computer running one of three operating systems (Windows NT, Mac OS and Unix). The paper discusses the pedagogical issues involved in the use of multimedia technologies for GIS instruction and outlines the design of the room, its costs and configuration, and how the room is used for live computer-based presentations. The paper concludes with a discussion of desirable, but not currently operational features.*

KEYWORDS GIS, video conferencing, classroom design, multimedia.

Introduction

Close to two decades have passed since courses in geographic information systems (GIS) first began to appear in geography and associated disciplines in North America and Europe. GIS courses are now firmly established within the mainstream curricula of university programmes world-wide. Further, GIS programmes have penetrated well beyond the universities in which they were spawned and are now taught as part of the high-school geography curriculum at many schools across Canada and elsewhere (http://www.esri.ca/k-12/index.html). Specialist diplomas are offered in many community colleges and polytechnics and specialist interdisciplinary programmes offered in cognate areas, typically with a 'spatial information science' orientation, are relatively commonplace. Much of this growth in GIS education has occurred during an era in which the information technology industry has, itself, undergone a rapid transformation.

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The fast pace of change has meant that instructors of cartography and spatial analysis at all levels have been required to retool their courses, not only in terms of *what* they teach, but more importantly in terms of *how* they teach it. A decade ago, personal computing had not made the inroads into, especially, undergraduate and high-school-level geography instruction that it now has. Many students are now not only conversant with stand-alone and networked personal computing when they arrive at university; they demand almost daily computing access in order to complete their degree requirements. These demands have had a concomitant effect on the viability of the traditional teaching approaches used in geography curricula prior to the GIS and information technology era. GIS instructors have struggled, especially over the past decade, to devise and deliver curricula that are informative, interesting and relevant to the needs of a changing workforce, while staying abreast of the rapidly evolving computing industry.

Assimilation of the emerging computing technologies and their impacts on instruction have been difficult to manage. In many instances, the pace of change has caused modes of teaching and learning to fall well behind the capabilities of software and to focus on the lower two levels of Marble's (1998) GIS education pyramid. In fact, at some institutions the ability to expose students adequately to *all* aspects of GIS technology has ceased to be a practical objective. Instead, courses and curricula have been developed around subsets of topics that tend to be either *generic*, where GIS concepts are taught and practical 'hands-on' work is modest, or *specific*, where concepts and practical hands-on work are customised to one or two software packages. In other situations, the generic and specific approaches have been combined in a single, integrated GIS curriculum that includes aspects of spatial modelling, GIS application design and implementation, as well as the more generic topics. Independent of the content and objectives of specific GIS curricula, the method of teaching used in the delivery of GIS courses has had to adjust to the needs of the subject matter and student expectations. Typically, this change has been from traditional 'chalk and talk' lecture delivery, to one which utilises computing technology as much as possible in 'live' presentation mode. In the transition from blackboard to include keyboard, a heavy emphasis has been put not only on teaching style but also on the technology-related infrastructure required to support instructional computer use in the classroom.

Support infrastructure in this context includes not only the physical infrastructure (such as lecture rooms and access to well-maintained computer networks and laboratories for practical work), but also the human resources (both technical and conceptual) required to support innovative use of computing technology in GIS course delivery. In this paper, we focus on one aspect of the physical infrastructure, namely the role and implementation of a new generation of multimedia classroom that incorporates computing technology designed to satisfy a variety of teaching and learning needs. In this paper, we separate considerations of support infrastructure from a particular style of teaching and from student response to and interaction with the instructor. This separation is based on the premise that a basic objective of multimedia classroom design should be to provide an enabling environment in which many possible modes and styles of teaching delivery and interaction can be supported, including remote and distance learning via video linkage.

Multimedia classrooms have been implemented with reported success at several universities (for example, the University of Colorado at Boulder (Niemeyer, no date) and Case Western Reserve University (Neff, no date)) and are used for student instruction in a variety of subjects. In the following discussion, we describe our experiences at the

University of Waterloo in establishing a multimedia classroom, with the equal objectives of providing:

1. a high-resolution, computer-based classroom for teaching courses that require lecture-based live presentation of specific software packages, especially GIS; and
2. a hardware configuration capable of high-speed, high-quality video linkages for teaching at remote sites.

First, we consider the pedagogical issues relating to the evolution and use of a multimedia classroom for teaching GIS. Following this, we outline the approaches used in GIS instruction prior to the development of this classroom at the University of Waterloo. We then discuss classroom design issues to enable interactive GIS instruction and describe the use of the facility in lectures and special presentations. We conclude with a summary of the main points and a consideration of design issues that may be of interest to those planning to develop similar classrooms elsewhere.

Pedagogical Considerations

The focus of this paper is on the design of a multimedia classroom that enables the deployment of various approaches to instruction including, but not limited to, a GIS curriculum. Although the discussion is devoted more to design and operational than other considerations, the importance of pedagogical and GIS curriculum issues cannot be diminished. Moreover, consideration should also be made of the pedagogical implications of multimedia classrooms for geography instruction in general.

For a general overview of the educational objectives of GIS, the University Consortium for GIS (UCGIS) white papers on 'GIS Education Priorities' (Wright & Kemp, 1997) are worthwhile starting points. In these documents, the *delivery* of GIS instruction is not considered explicitly; however, it is noted that 'an additional area that might warrant further study' includes the use of technology in GIS education. Central to this consideration is the need to teach students GIS *concepts*, while allowing them to gain practical 'hands-on' experience with specific software packages. Here, one must be mindful of the need to teach more than just the fundamental concepts of GIS and spatial analysis in a GIS curriculum, and to include also courses that allow students to explore and become competent in the full capabilities of the technology. Toward this end, there are many possible pedagogical approaches that one can draw upon. These include modes of GIS instruction that use videos in conjunction with conventional classroom-based lecture presentation (Hall & MacLennan, 1990) and the use of lab-based, self-paced, stand-alone electronic GIS 'tutor' software (Environmental Systems Research Institute, 1998; Raper, 1991; Raper & Green, 1992). There are also newer modes of learning GIS, such as use of the Internet and Worldwide Web to create virtual classrooms (for example, http://campus.esri.com/) in which students can learn GIS via self-paced distance learning as the mode of delivery (Wright *et al.*, 1997). The UNIGIS programme is another example of this type of approach (http://www.unigis.org). There is still, however, no clearly better substitute for classroom instruction, with the qualification that the nature of the classroom best suited to teaching computer-based and highly visual material, such as GIS, must accommodate the needs of the subject matter.

Certainly, the role of supporting infrastructure is of central importance in the pedagogical style that is adopted in the delivery of GIS courses. Some of the key considerations in this are summarised by Macey (1997). Nellis (1994), Brimicombe, (1993) and Palladino and Kemp (1991) discuss the acquisition of technology and the development of computer laboratory equipment for geography in general. However, there is relatively little in press that provides guidance on this important topic.

In order to harness the capabilities of modern information technology in the delivery of GIS courses, it is necessary first to identify a workable set of pedagogical goals for GIS instruction and, subsequently, to consider the use of technology and the supporting infrastructure that is required to achieve these goals. Both the goals and the support infrastructure serve to define the substance of a particular GIS curriculum. In this context, we offer a number of interlocking and generally hierarchical, instructional goals that we have used in our approach to GIS instruction, namely, to achieve an understanding of:

1. the types of issues and problems GIS software and associated spatial data technologies are appropriate to address and solve;
2. the technicalities of spatial and attribute data creation and maintenance;
3. the pitfalls of failing to achieve acceptable spatial data standards;
4. the use and enhancement of spatial models within the GIS software environment; and
5. the development of end-user GIS applications, using standard and customised software environments, for routine spatial data processing tasks and special 'one-off' applications work.

Our experience, in working toward these goals, is that sole reliance on traditional 'chalk and talk' delivery of GIS instruction leaves a significant 'discomfort zone' for students between learning GIS 'by being' (learning concepts and technicalities in the traditional classroom/lecture theatre), and learning 'by doing' (ex-classroom use of GIS software 'hands-on' in a computer laboratory environment). Reducing the discomfort zone requires adoption of a mode of teaching and learning that integrates, as best as possible, traditional classroom-based teaching with hands-on software use. Thus, within an appropriate enabling environment, students can be taught both the concepts and capabilities of the technology (instructional goals 1, 2 and 3), as well as how actually to do things with it (instructional goals 4 and 5). As suggested above, conventional pedagogical approaches, which focus solely on lecture-based teaching of GIS concepts, only satisfy the former set of these goals.

Flexibility is the cornerstone of creating an environment that facilitates the use of various modes of GIS instruction. Hence, it is necessary to develop a supporting infrastructure that provides for maximum flexibility in the mode of instructional delivery. Moreover, the support infrastructure must be separated out from any one specific teaching method in order to satisfy the complete set of teaching and learning objectives. This allows the same set of resources to be reused in different pedagogical contexts (e.g. distance learning, on-campus instruction, continuing education, regular courses, virtual classroom instruction, and remote teaching by video linkage).

A further important pedagogical consideration in crafting this support environment is its ease of use for expert and non-expert instructors alike. That is, the environment must intimidate neither teachers nor students. The instructor must have confidence that the environment is robust and that the equipment will not fail. Further, there must be minimal learning and set-up time required to commence lecture presentations—at least no longer than the time normally required to place lecture notes and position an overhead projector, screen, and blackboard in a conventional classroom. Few new pedagogical models exist to assist in deploying teaching materials in these environments.

From a student learning perspective, the environment must be fully conducive to maximising the learning experience. In GIS courses, this requires that students be taught important principles and concepts in traditional lecture mode, *as well as* the processes by which these concepts are operationalised on the computer. Efforts at the University of Waterloo to achieve such a teaching and learning environment for both instructors and students is discussed in the following sections. This is prefaced by a discussion of problems experienced with use of successive modes of GIS instruction that led to the development of the new multimedia classroom.

Previous Situation

Undergraduate courses in computer cartography and remote sensing were first offered in the Faculty of Environmental Studies at the University of Waterloo in 1969. Undergraduate courses in GIS were first offered formally in 1989. A new GIS curriculum has also been introduced recently that leads to a specialist Certificate in GIS as well as a regular undergraduate degree in Environmental Studies. Currently five undergraduate courses are offered in GIS, commencing with a 200 level (second year) introductory course, and culminating with a 500 level course (graduate and undergraduate students), focusing on management issues. The 300 level course focuses on database design and creation issues, while two 400 level courses examine, respectively, methods of GIS-based spatial analysis and GIS applications development and programming. These courses are offered by both the geography department and the school of planning.

At the outset of GIS instruction at Waterloo, the computing resources available to students were best described as very modest by current standards. The computing environment has evolved considerably over the last half decade with two teaching laboratories established for GIS courses (as well as related courses in digital cartography and remote sensing): the laboratory used by the 200 level course contains 30 networked Windows 95 computers and the lab for the senior courses contains 18 networked Windows NT computers (three of which are digitising stations). Each laboratory is managed by its own NT server, which is in turn connected to the UW backbone network and externally to the Internet.

Initially, the GIS courses focused on teaching students GIS concepts and software use through traditional combinations of blackboard, overheads and hard-copy handouts. GIS instructors were required to make repeated visits to the laboratories, as were teaching assistants and technical computing support staff, to help students complete assignments and learn the software. The excessive time required to respond to student questions, combined with the exigencies in senior courses for the students to learn a complex command line-based software package (workstation ARC/INFO), suggested that the discomfort zone between classroom and laboratory was too large.

Despite the information technology orientation of the University of Waterloo, classrooms are not designed appropriately or universally equipped for on-line computer presentations. Further, large class sizes (up to 90 students per term in the second-year course; 25–40 for the third-year course; and 15–30 for the fourth-year courses) effectively preclude the possibility for small group interaction on the computer during lectures. The university has addressed this need in a significant component of the 1998 Computing Directions Statement (http:www.adm.uwaterloo.ca/infocist/Directions1998.html).

Initial attempts to bridge the classroom–laboratory gap in GIS teaching involved establishing Ethernet links to specific classrooms. This allowed GIS instructors (and others) to connect to the network and project from a portable, but cumbersome, SONY VGA high-resolution projector onto a pull-down screen. Student learning was improved by allowing the instructor to demonstrate in class the use of GIS software and spatial analysis. The approach, in effect, replicated the laboratory in the classroom through loosely coupled 'learning by doing' without compromising the learning of GIS concepts or 'learning by being' using conventional methods (blackboard, overheads and handouts) in the same classroom environment.

With this approach, the physical preparation of equipment for each lecture required a significant time commitment as an audio-visual technician was required to move the projection unit into the classroom, and then connect and calibrate it for use. In addition, a computer had to be moved into the classroom and connected to the network. The fact that the projector was one of only two for a campus of over 21 000 students meant that windows of opportunity for use had to be exploited and there was not much flexibility. Further, there were frequent equipment failures, which served to undermine student and instructor confidence in the approach.

Notwithstanding the efforts to 'create' a satisfactory environment, additional problems in teaching delivery involved unsatisfactory classroom lighting (either completely dark or too light to see the projected computer screen adequately). Also, the projection screen often obscured the blackboard, effectively precluding simultaneous use of live computing presentation and blackboard-based explanation. This could be overcome to some extent with creative use of the computer and overhead transparencies, but the net effect was a clumsy switching of teaching delivery modes. There was, none the less, an improvement in bridging the discomfort zone between concept-based GIS teaching and student end-use of GIS software for problem solving. Further, the frequency of visits to the laboratory to help students diminished considerably.

Interest in harnessing more recent developments in multimedia technology to coalesce the desirable characteristics of GIS teaching described above and to overcome persistent instructional problems led to the desire to establish a true multimedia classroom that could serve the teaching needs of GIS and other courses. In this there was a number of basic objectives:

1. to allow networked and stand-alone computer presentation and stand-alone overhead projection at the same time, thus allowing teachers to operate on dual screens, respectively, a live computer presentation and to display projected notes and overheads to students;
2. to be able to switch seamlessly between teaching modes as required;
3. to provide proper lighting control;
4. to provide satisfactory resolution to carry 1024 by 768 video with up to 16 million colours for a variety of operating systems (Windows 95, NT, UNIX and Mac OS);
5. to control delivery mode from an easy-to-use central touch-screen console built into the lecture podium;
6. to minimise the need for technical support staff involvement in setting up and maintaining the teaching equipment; and,
7. to make the operation of the room robust and not prone to frequent equipment failure.

The creation of this teaching environment is described in the following section.

Current Room Design

In 1996, work began on the development of the ACCESS (*ACC*ounting and *E*nvironmen-

TABLE I. Costs of major ACCESS room components. All figures in 1996 Canadian dollars

Item		Amount
Video Conference System		
Equipment, Services, Installation		162840.73
Maintenance (annual)		13034.74
Cable converter		121.29
Control for Video Converter		1627.07
Camera and 3.5″ LCD screen		4423.42
	Subtotal	**182047.25**
Projectors and Screens		
	Subtotal	**58545.93**
Computer System		
VGA Monitor		605.6
Pentium Computer		3396.44
Sound Card		117.13
	Subtotal	**4119.17**
Infrastructure		
Telephone lines		2123.57
Security System		1177.59
Network Cabling		432.43
Sytek Drop		24.89
	Subtotal	**3758.48**
Room Renovation & Construction		
	Subtotal	**75448.94**
Total for Facility		**323919.77**
Total Less Annual Maintenance		**310885.03**

tal *S*tudies *S*mart) classroom in space provided by the Faculty of Environmental Studies. The work was funded jointly by the Accounting Department, in co-operation with two corporate sponsors, and the Faculty of Environmental Studies. A request for proposals and subsequent evaluation of applicants was undertaken prior to equipment selection. The final configuration was judged to offer the best solution to the dual objectives of the room for the overall available budget.

Costs, broken down into major categories, are presented in Table I. It must be noted that the figures are in 1996 Canadian dollars. Cursory examination of the table reveals that the video conferencing equipment is the most expensive component. Moreover, it is worth noting that virtually all areas of expenditure are now cheaper, in some cases considerably, than in 1996. For example, it is now possible to purchase video projectors with 1024 × 768 resolution and 1200 lumens compared to 400 lumens for the current projectors. The newer models also have both front and rear projection capability and are approximately 50 per cent of the 1996 cost. Further, the cost of a Pentium workstation is approximately one-third of that noted in Table I.

By simply subtracting the video conferencing component of the costs, some idea of the 1996 costs of development relative to the needs of the GIS and other multimedia courses can be obtained. It is worth noting, also, that approximately 25 per cent of the total budget was devoted to renovation and construction costs.

The room was officially opened on 12 February 1997 and has been in full operation for three years. It is a 50-seat, wheelchair accessible auditorium with two

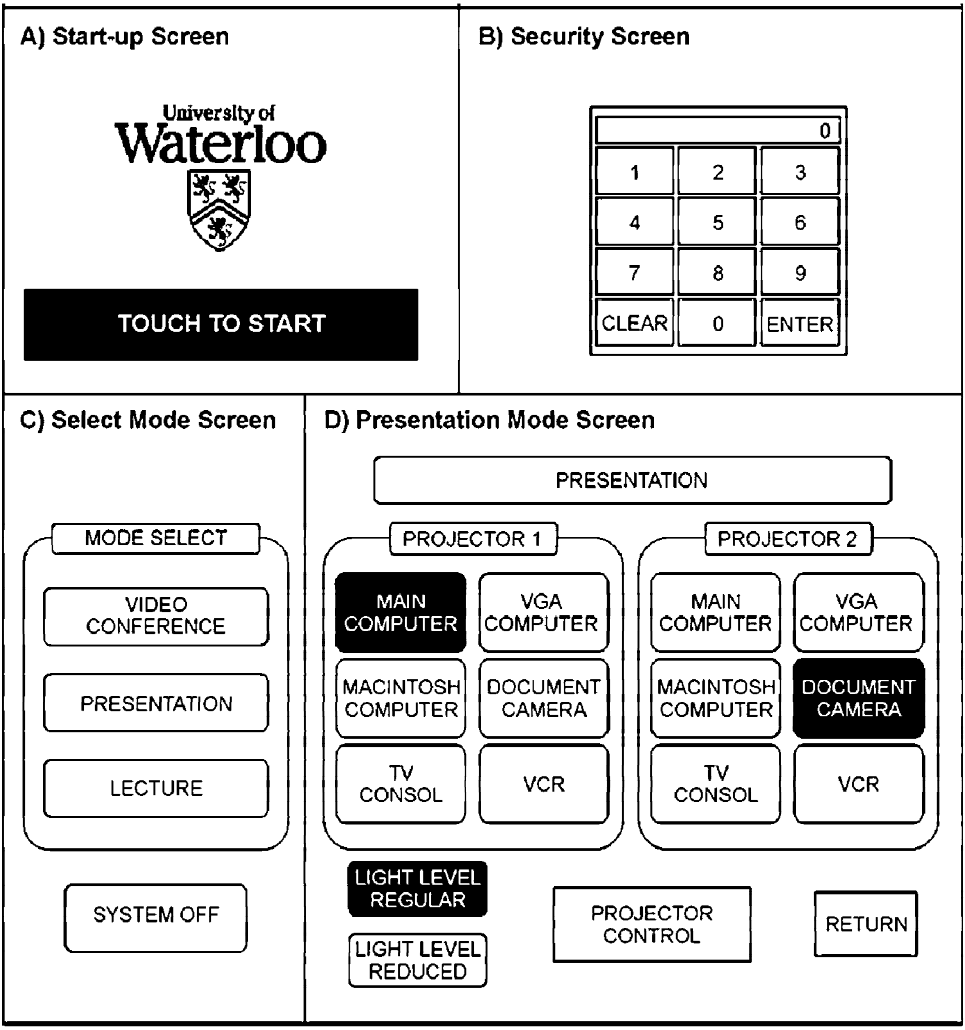

FIGURE 1. Control menu layouts.

100-inch, fixed projection screens at the front. A liquid-crystal touch-control panel mounted on the lectern console allows the instructor to switch between (and configure) three teaching modes: conventional lecture, multimedia presentation and video conferencing. By scrolling through a series of screens, the instructor may select the projection source and the lighting level. For a typical computer-based presentation, such as is used for GIS instruction, a security code must be entered to access the system, and on the subsequent screen the presentation mode would be selected (Figure 1). Subsequently a choice must be made from six options: main computer, VGA laptop, Macintosh laptop, document camera, television, or VCR. As noted above, the instructor may also select a regular or reduced light level. Instructors may choose to present material on both screens from a PowerPoint presentation on the main computer. Alternatively, they could choose to show hand-written notes, sketches, or overheads on one screen with the document camera, while running a GIS programme, such as ARC/INFO or ArcView, on the main computer projected on the second screen.

The room can be operated in two distinct but not always independent modes: multimedia presentations and video conferencing. The former are of particular concern in the context of GIS instruction, while the latter, although relevant to GIS needs, is more central to the requirements of the School of Accounting to facilitate their distance learning courses at other university locations in Ontario. The design requirements for each mode, and the corresponding features of the room, are described below.

Multimedia Design Issues

To support multimedia presentations, the room is equipped to support on-line computer application, VCR, computer slideshow and presentation software, CD-ROM (audio and computer), transparencies and photographic slides. Multiple computer hardware and operating systems (UNIX, Mac and Intel-based) can be accessed. As noted earlier, accommodation is made to allow instructors to connect their own laptop computers to the multimedia control centre with a minimum of fuss and technical support. Further, instructors can select the lighting level best suited to the material being presented. Since every moment in a presentation will not necessarily consist of multimedia components, the room also supports a traditional lecture style by incorporating a whiteboard and allowing suitable lighting levels and site lines.

For all of the multimedia options, simultaneous display is possible from multiple input devices. This can be accomplished by using the two screens at the front of the room or by tiling the large screen and selecting various input sources for each screen tile. It is then possible to have, for example, a presentation on a specific GIS application on one screen while running a demo of the application on the other screen, or a presentation of a GIS-based digital image of an area on one screen and photos or video of the area on the other screen.

Design Features for Multimedia Presentations

The current configuration of the ACCESS room for GIS and other multimedia presentations is shown in Figure 2. At the front, a wall was constructed to hold the two 100-inch rear projection screens. The projectors for these screens are located in a room situated behind the front wall. This configuration provides a high level of security, while reducing any obstruction of sight lines that might be caused by mounting the projectors on the low ceiling of the classroom. Each of the screens has a retractable cover mounted in the ceiling that can be lowered when the system is not in use and for the presentation of slides and overhead transparencies. The lectern is located to face left of the projection screens in the front corner of the room. Although this configuration requires students to look to the side in order to maintain eye contact with the instructor, the low ceiling in the current room would not allow a configuration in which the lectern was located front and centre with the projection screens above (this may be a feasible alternative in a larger room with a deeper floor-to-ceiling height).

A whiteboard, mounted on the wall behind the lectern, allows the room to be used in a traditional lecture format in conjunction with use of overhead transparencies or projection of notes via the document camera. This configuration of equipment provides a robust hardware environment that does not need to be set up and disassembled for each class, thus significantly reducing preparation time.

The computer system put in place in early 1997 was replaced in 1999 to provide better support for the advanced GIS software and related applications. Prior to this upgrade,

FIGURE 2. View of the front of the ACCESS room during a GIS lecture.

400-level GIS students demonstrating their final projects discovered that their applications took 3–4 times longer to run in the ACCESS room than in the student laboratories, solely because of the differences in computer hardware. The current system runs under Windows NT 4.0. GIS software installed includes ArcView, ARC/INFO (NT only) and IDRISI. Other software installed and used in non-GIS instruction includes AutoCAD, TNTMips, Netscape and Microsoft Office Professional. Network connections and a ZIP drive allow instructors to transfer previously prepared digital lecture materials from the computer in their office to the computer in the ACCESS room, or to run external software, such as PCI EASI/PACE image processing software via an X-terminal to a UNIX server. Network shares can also be established to office computers to run remote applications. In addition to this 'main' computer, there are video ports and cables that allow instructors to hook-up both Mac and PC (VGA) laptops.

Video Conference Design Issues

A number of the initial design criteria in the ACCESS room planning was aimed at facilitating video linkage for the School of Accounting and other users. These criteria can be categorised into instructor, student and room-related issues.

Instructor. The main design issue related to a lecture by video linkage is tracking the instructor's movements around the room. Tracking must be accomplished for both video and audio. The solution is to have the instructor wear a microphone pack containing a homing beacon that is detected by a video camera in the room. It is best if the video camera can be situated away from the line of sight for students in the classroom—prefer-

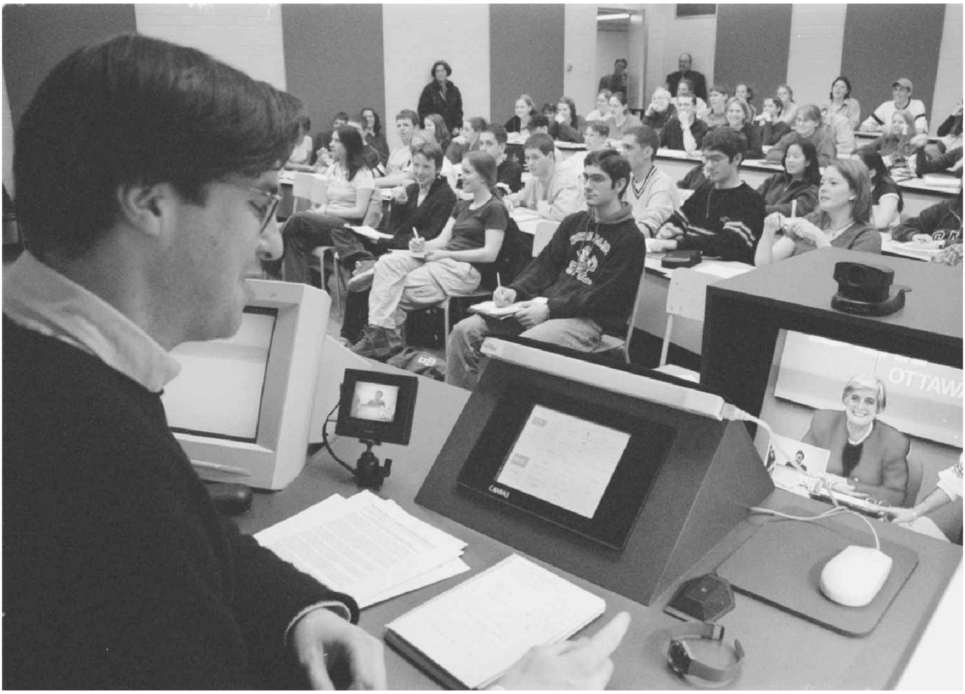

FIGURE 3. View from the front of the ACCESS room showing the podium during a video conference.

ably suspended from the ceiling or affixed to the walls of the room. An alternative is to place a camera and microphone at a control station and limit the extent to which the instructor can roam to the camera's field of view and audible range of the microphone. In this case, the broadcast area should be large enough to support group presentations.

It is essential for the remote students to be able to see and hear the linked classroom. Of equal importance is that the instructor be able to see the remote audience clearly. This can be accomplished by front projection or by suspending a large screen monitor from the ceiling of the class (again out of the site line for students in the classroom) and by placing a screen at the control panel for the instructor. At the remote site, audience cameras must be used to transmit images of the students back to the instructor.

Any video conference set-up will only be as good as the quality of the transmission signal. To provide a picture and audio flow that is fluid, the room should support six lines for teleconferencing (audio and video). With six lines active in teleconference mode, the transmission should approach 30 frames per second and the audio will be relatively smooth. With only two lines dedicated for video conferencing, viewers at the remote site will experience broken and delayed audio feed and a video transmission of between 10 and 14 frames per second. At these rates, the video becomes stilted and resembles the transmissions from the early US Apollo moon shots.

Students. In order to facilitate and promote two-way interaction between students and the instructor, the students should be able to ask questions with a minimum of disruption to the flow of the lecture. To avoid passing around microphones or moving to a central area to ask a question, a student should be able to ask a question while seated and be picked up by both video and audio feeds. Microphones should be touch activated (as opposed

FIGURE 4. View of the front of the ACCESS room during a video conference.

to voice activated!) and be tied into the video camera targeting system. In the event of a multiple-site video conference, student interaction should work seamlessly, irrespective of the site from which they are broadcasting.

Room. To minimise the disruption during video conferencing, the room should be designed to allow students to enter and leave at the back (and therefore avoid crossing in front of the camera). Ideally, the room should be graded to provide amphitheatre-style seating while maintaining accessibility via wheelchairs, etc. and line of site should be maintained between the students and the instructor at all times.

Design Features for Video Conferencing in the ACCESS Classroom

In the ACCESS classroom, there are two video cameras, each able to pan, tilt and zoom as required. One camera is trained on the audience. A second camera is primarily trained on the instructor but, with a 360-degree field of view, it is capable of pivoting and focusing on audience members also. Currently the camera is unable to track automatically a moving instructor. The instructor may view the students at the remote location on a large video monitor mounted on the floor of the classroom just in front of the control lectern (Figure 3). Students in the room may view the remote location on the two 100-inch projection screens at the front of the room (Figure 4). Audio is picked up from one microphone at the instructor podium and 25 touch-activated low-profile microphones in the audience (i.e. one microphone shared between two seats). The video camera that is trained on the classroom is capable of zooming in on the students who activate their desktop microphone. Audio signals from the remote location are broadcast over four speakers. The room is equipped with a BT VC2400 CODEC unit to compress audio and video for transmission over the six telephone lines (three ISDN lines).

Discussion

Evaluating the effectiveness of a multimedia classroom requires that we address a central question that is similar to one outlined by Rich *et al.* (1997), namely can information technology, in a setting such as the ACCESS classroom, provide an experience that is qualitatively better than that of traditional approaches? Although most people might assume that the answer to this question is ‘yes’, a number of authors has outlined potential concerns related to the use of multimedia technologies in educational settings (Cárdenas, 1998; Dickson & Segars, 1999; Flowerdew & Lovett, 1992; Jones & Smart, 1998). Some of these concerns focus on the potential problems that can arise with the implementation of multimedia-based teaching solutions (Flowerdew & Lovett, 1992). Other concerns focus on the more fundamental issue of where use of a specific technology in a specific pedagogical setting has adversely affected communication between students and instructors (Cárdenas, 1998; Dickson & Segars, 1999; Jones & Smart, 1998). Specifically, their concerns focus on situations where the limitations of the technology serve as a limitation to effective communication. Citing examples on the limitations of electronic discussion groups and video conferencing, the authors caution potential adopters of new technologies to consider the potential limitations of the medium as well as its advantages. Although these authors do not focus specifically on geography or GIS education, some of their general concerns are none the less potentially applicable to the discussion here. In the following section, we present some of the observed limitations and advantages of the multimedia classroom and relate them to the discussions of other authors.

Limitations and Shortfalls

The general consensus amongst users of the ACCESS room is that it is very successful for GIS and other multimedia presentations as well as video conferencing. However, three years of experience has identified some limitations with the current room design. These are outlined below.

The Wandering Lecturer. The room configuration, especially in video conference mode, does not accommodate movement by the instructor to any great extent. As noted above, the lectern is located in the left facing corner of the room in front of the whiteboard, and it houses the instructor’s microphone, confidence monitor, and a 25-inch video monitor for viewing remote sites. Cárdenas (1998) notes that with this configuration, instructors are inflexibly tied to the lectern in order to maintain control over the mechanics of the presentation. Particularly for non-video linkage GIS presentations with instructors who like to wander or be closer to the audience, the presence of the computer in the lectern presents a tie to this spot and the lectern itself presents somewhat of a barrier between the instructor and the class. Either a less obtrusive, less massive, and more centrally located lectern, or use of a remote control mouse would go a long way to reducing the effect of this barrier. For multimedia presentations, one instructor has already purchased a remote control mouse so that she does not have to be near the lectern to operate software.

Slide Projector. Currently there is no 35-mm slide projector in the room. While not useful for video conferencing, the multimedia capabilities of the room would have been complete with this addition. For individual slides, instructors can use the document camera with back-lighting and zoom in on the 35-mm slide but this solution is not practical for lengthy slide shows. To present slide shows, a projector must be placed in the audience, or the instructor must invest preparation time in scanning slides and including them in a PowerPoint presentation. In addition, the two retractable screens can only be raised or lowered in unison. Separate controls for each screen would allow one to be lowered for 35-mm slides with the other raised, allowing software demonstrations or other digital information to be displayed simultaneously.

Multiple Input Sources. While the instructor can mix and match most combinations of input devices onto the two large projection screens, it is not currently possible to have a laptop and any other device displayed simultaneously. This limitation was a cost consideration.

Benefits

Relative to the teaching objectives and the curriculum delivery previously noted, the ACCESS classroom certainly has reduced the discomfort of teaching concepts without access to live GIS software use. Moreover, it has ensured improved robustness over the previously used portable presentation approach. Students and instructors alike have commented on the ease of switching between, for example, a PowerPoint slide show of lecture material, actual GIS software use, and combination of document camera and whiteboard as substitutes for the chalk component of the traditional 'chalk and talk' approach. All of these input sources make it easier to take advantage of a wide range of pedagogical approaches and instructional materials.

Important GIS concepts can now be presented conceptually and illustrated with a real-time software demonstration. Laboratory exercises and many of the complicated steps involved in geo-processing can be demonstrated live to the entire class. This allows the instructor to emphasise potential problem spots in class before the students go to the laboratory for the 'learning by doing' aspects of their work. The instructor can also respond to student questions effectively by illustrating answers with a quick demonstration. For courses that incorporate GIS software application development that requires programming, instructors are now able to design, code, test and run programs with the students in a classroom environment. The room is also especially useful for the presentation of student projects.

For the 500-level GIS course, many lectures consist of presentations by non-university personnel including vendors, consultants and government officials. Many of these outside presenters come with presentations and applications on laptop computers. The ability to plug in a laptop and display the presentation or application on two 100-inch screens has made for effective and efficient use of everyone's time and effort.

Despite some of the limitations mentioned above, the ACCESS room has greatly improved GIS instruction at Waterloo. The facility has substantially overcome many of the technical and pedagogical hurdles noted earlier in this paper and noted by Flowerdew and Lovett (1992). The room has also qualitatively improved the educational experience for students who can now be taught *both* the concepts of GIS and spatial analysis, and the implementation of these concepts in a specific software package. Instructors within the GIS programme now have a medium that is appropriate for the presentation of the dynamic and visually oriented themes of GIS technology. Although ongoing upgrades to equipment will be required, the classroom has allowed instructors to experiment with the use of multimedia in GIS and other courses in geography and associated disciplines. This experimentation has, in an ongoing manner, allowed us to refine our approach to instruction with a more complete array of possibilities that would have otherwise been impossible.

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REFERENCES

BRIMICOMBE, A.J. (1993) GIS laboratories: perpetual motion, perpetual money, *Geo Info Systems*, 3(4), pp. 453–456.

CÁRDENAS, K. (1998) Technology in today's classroom: it slices and it dices, but does it serve us well, *Academe*, 84(3), pp. 27–29.

DICKSON, G.W. & SEGARS, A. (1999) Redefining the high technology classroom, *Journal of Education for Business*, 74(3), pp. 152–156.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. (1998) *Getting to know ArcView GIS: the geographic information system (GIS) for everyone* (Redlands, CA, ESRI Press).

FLOWERDEW, R. & LOVETT, A. (1992) Some applications of Murphy's law: using computers for geography practical teaching, *Journal of Geography in Higher Education*, 16(1), pp. 37–44.

HALL, G.B. & MACLENNAN, M. (1990) Video support in teaching about GIS: a review of six videotapes, *International Journal of Geographic Information Systems*, 4(1), pp. 87–96.

JONES, S.P. & SMART, K.J. (1998) Humanness under assault: an essay questioning technology in the classroom, *Bulletin of Science, Technology & Society*, 18(2), pp. 87–95.

MACEY, S. (1997) Supporting Infrastructure, Infrastructure Working Group, Education Committee, University Consortium for GIS (UCGIS), http://www.ncgia.ucsb.edu/other/ucgis/ed_priorities/infrastructure.html (June).

MARBLE, D. (1998) Rebuilding the top of the pyramid, *Arc News*, Spring, pp. 1, 28–29.

NEFF, R.K. (no date) *The classroom of the future*, unpublished manuscript, Case Western Reserve University.

NELLIS, D. (1994) Technology in geographic education: reflections and future directions, *Journal of Geography*, 93(1), pp. 36–39.

NIEMEYER, D. (no date) *Enabling technology in smart classrooms at the University of Colorado*, unpublished manuscript, Academic Media Services, Campus Box 379, University of Colorado, Boulder, CO.

PALLADINO, S.D. & KEMP, K.K. (Eds) (1991) GIS teaching facilities: six case studies on the acquisition and management of laboratories (Santa Barbara, National Centre for Geographic Information and Analysis, Department of Geography, University of California at Santa Barbara, Technical Paper 91-21).

RAPER, J. (1991) Using computer demonstrators and tutors in GIS teaching: lessons from the development of geographical information systems tutor, *Cartographica*, 28(3), pp. 75-87.

RAPER, J. & GREEN, N. (1992) Teaching the principles of GIS: lessons from the GIS tutor project, *International Journal of Geographical Information Systems*, 6(4), pp. 279-290.

RICH, D.C., PITMAN, A.J., GOSPER, M. & JACOBSON, C. (1997) Restructuring of Australian higher education: information technology in geography teaching and learning, *Australian Geographer*, 28(2), pp. 135-157.

WRIGHT, R. & KEMP, K.K. (1997) GIS Education Priorities, Education Committee, University Consortium for GIS (UCGIS), http://www.ncgia.ucsb.edu/other/ucgis/ed_priorities/

WRIGHT, D., ELMES, G. & FOOTE, K. (1997) Emerging Technologies for Delivering GIScience Education, Emerging Technologies Working Group, Education Committee, University Consortium for GIS (UCGIS) http://dusk.geo.orst.edu/emerging/(29 June).