A Modular E-Learning Environment to Teach GIS to On-Campus and Distance Education Students[1]

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Abstract

Courses in geographic information systems (GIS) are now firmly established within the mainstream curricula of university programs world-wide. Recent changes in information technology have challenged instructors not only in terms of what they teach, but more importantly in terms of how they teach GIS. Our goal was to develop an e-learning environment that stimulates the higher-order cognitive skills of students such as geographic abstraction and critical thinking. Our specific objectives were: (1) to build a virtual modular learning environment based on the Reusable Learning Objects (RLO) concept and (2) to evaluate the efficacy of different e-learning tools for on-campus (OC) and distance education (DE) students in context of learning outcomes. We built a virtual GIS computer laboratory which provided GIS datasets, software and applications. Results from a survey showed that DE and OC students learning outcomes were comparable. DE students faced barriers of time management and less computer literacy. The RLO environment was well received by DE and OC students because of organizational clarity and transparency. A virtual GIS course has the potential to generate equal learning outcomes comparable to on-campus GIS courses provided students are self-motivated to study the course material and capable to manage their time.

Introduction

Courses in geographic information systems (GIS) are now firmly established within the mainstream curricula of university programs world-wide. Recent changes in information technology have challenged instructors not only in terms of what they teach, but more importantly in terms of how they teach GIS. The availability of geographic datasets is growing exponentially and geographic information technologies have changed the way we manage, display and interpret geospatial data representing geologic formations, soils, topography, land use, land cover and more (Fisher and Unwin, 2002). Yet learners need to develop an understanding of "how to conduct geospatial modeling" and "how to use a specific spatial function to address a geographic problem". Students are challenged to develop abstract geographic thinking skills to comprehend the spatial and temporal distribution of land resources, their interrelationships with other environmental factors and processes, and the impact of human activities on land resources.

Geographic information systems are ideal tools to manage, analyze, and display geospatial data (Burrough and McDonnell, 1998). However, teaching GIS is not limited to rehearsing geospatial terminology and to repeating basic GIS functions (e.g. import and print a map). Rather to successfully teach GIS there are two equally important aspects. First, to teach students how to operate a GIS and how to select and employ specific geospatial functions for specific tasks. Second, to teach GIScience, i.e., to synergize GIS operations to solve a geospatial problem, to comprehend and integrate huge amounts of geospatial data, and facilitate understanding of both large-scale and small-scale geographic features of ecosystems. This can be accomplished by stimulating the creative and abstract geographic thinking skills of students. Students are encouraged to immerse themselves into a virtual geographic world that consists of 2D and 3D geographic objects.

Spatial information technology per se does not

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determine learning outcomes. Rather, learning outcomes are influenced by the choices that instructors make about the organization of teaching and learning tools, choices about content, and the motivation of students to go beyond provided course material. The role of information technology is to expand the available choices.

Reusable Learning Objects (RLO) are elements of a new type of computer-based instruction grounded in the object-oriented paradigm of computer science. They provide a digital educational resource or "chunk" that can be reused, scaled and shared from a central repository in the support of instruction and learning (Hodgins, 2000; Urdan and Weggen, 2000). Each RLO supports a single learning objective. They include, but are not limited to, text entries, web sites, bibliographies, charts, figures, photographs, illustrations, assessments, tutorials, electronic calculators, simulations, audio and video clips. They vary in size, scope, and level of granularity ranging from small chunks of instruction to a series of resources combined to provide a more complex learning experience. In short, RLOs are altering the landscape of learning (e.g. MERLOT http://www.merlot.org/Home.po).

Our goal was to develop an e-learning environment that stimulates the higher-order cognitive skills of students such as geographic abstraction and critical thinking. Our specific objectives were:

1. To build a virtual modular learning environment, which is a compartmentalized educational framework based on the RLO concept. The learning environment provides a digital educational resource that can be reused, scaled, updated and shared from a central repository in the support of instruction and learning (Figure 1)

2. To evaluate the efficacy of different e-learning tools for on-campus (OC) and distance education (DE) students in context of learning outcomes.

Material and Methods

Course Description

The graduate level course SOS5720C GIS in Land Resource Management is a 3-credit course offered at the University of Florida. The course is an elective in the GIS certificate program coordinated by the Interdisciplinary Concentration in GIS. The distance education section is part of the Graduate Distance Education Environmental Science program offered by the Soil and Water Science Department, University of Florida (UF) (http://disteduc_ sws.ifas.ufl.edu/). The course is offered to OC and DE students each Fall semester. The objective of this course is to provide students with the basic concepts of, and experience in using, the ArcGIS software as applied to land resource management issues. The design of our course is rooted in cognitive science aiming to stimulate the abstract geographic thinking skills of students. The course material aims to engage students to learn about spatial modeling techniques applicable to a variety of land resource issues. A prerequisite to enroll in this class is high speed Internet access (Digital Subscriber Line (DSL), DSL light or cable/satellite modems).

During Fall 2003 semester the e-learning environment provided OC and DE students with a rich resource of synchronous and asynchronous learning tools summarized in Table 1. Student-centered learning media included lecture material in the form of PowerPoint slides with notes, digital reading material, hyperlinks to additional resources, digital movies of lectures, and quizzes. A virtual GIS computer laboratory provided students with a learning environment to work on hands-on GIS assignments. The lab component required the solving of traditional and topical GIS problems and was 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 addressing land resource issues (e.g. land use change, carbon sequestration).

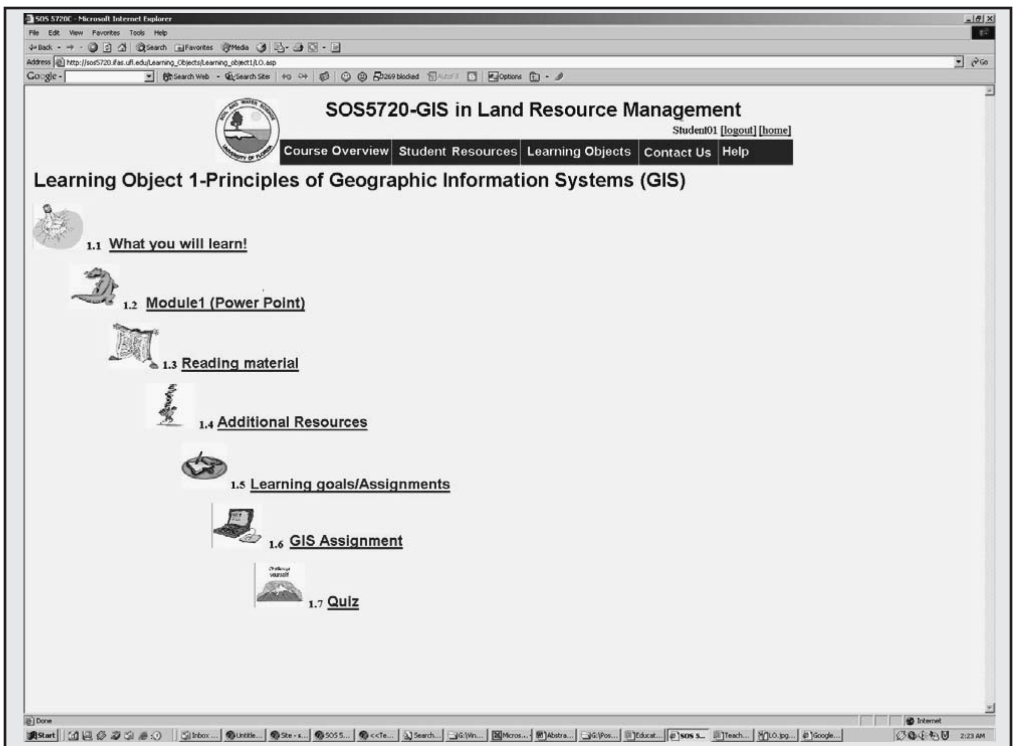

Figure 1: Example of a learning object (LO).

Detailed step-by-step instructions supported by snapshots of the ArcGIS-based spatial operations were provided to students guiding them through an application. At the end of each assignment students had to answer two to four questions closely related to what they just learned. Students had to employ their GIS knowledge to solve problems with new datasets provided to them. Tracking tools and checklists enabled students and the instructor to monitor learning progress. Other tools provided course-related information to students such as the course calendar, event board and grading tool. The on-campus section was comprised of two hours of lectures and two hours of labs each week. The off-campus section included one hour chatroom sessions each week in addition to emails and phone used to interact between instructor and students. Asynchronous interaction between students and instructor was accomplished using a message board. Off-campus students were encouraged to evaluate their learning progress and reflect on problems with course material biweekly in the form of self-reflective emails. Students were graded based on 10 GIS assignment reports (40%), a GIS project (30%), an exam (25%), and course participation (5%).

Table 1. Overview of tools and media used in SOS5720C.

Content tools	Information tools	Tracking tools	Interactive tools
Power Point slides with lecture notes	Event board (used to announce important course related events)	Checklist RLO	Classroom lectures[2]
Digital movies of lectures (Real Time Player format)[1]	Calendar	Checklist submission of GIS assignments	On-campus labs[2]
Reading material (compressed Portable Document Format – pdf)	Grading table	Checklist submission of self-reflective emails	Message board
Additional resources (e.g. hyperlinks)	Histogram (provides students average performance)	Checklist chatroom participation	Email
Interactive quizzes			Phone
GIS assignments			Self-reflective emails[1]
Virtual GIS computer lab (provided GIS data and access to the ArcGIS software)			Chatrooms[1]

[1] only available to DE students
[2] only available to OC students

We developed a modular e-learning environment based on the RLO concept. The aim was to provide students with a concise organizational structure of course material. From a pedagogical perspective we considered cognitive science during the design of our computer-aided instructional tools to enhance effectiveness in achieving learning outcomes. While some students have text or visual learning styles, others have auditory learning styles. Therefore, we used a variety of contextualizations for RLOs customized for different learners. For example, the same learning material was provided in form of reading material, PowerPoint slides, a Flash animation and a digital movie to reach students with different learning styles. We addressed the following learning mechanisms:

1. Explanation based learning ("chunks of knowledge") packaged in the form of PowerPoint slides, reading material, and other
2. Redundancy-based learning (the same content provided in the form of different media (e.g. PowerPoint slides, maps, graphics, reading material, discussion in chatrooms, flash animations, etc.))
3. Response-strengthening learning which involves strengthening or weakening associations between a stimulus such as 2 + 2 = __ and a response (e.g. GIS assignments)
4. Analogy learning through GIS assignments, GIS demos in the classroom and case studies (i.e., students were stimulated to determine similarities between GIS examples and real-world land resource problems)
5. Learning based on problem-solving and critical thinking skills (e.g. GIS assignments)
6. Abstraction learning through a hierarchy of abstraction spaces (e.g. from simple text to 2D maps to 3D models; students learn how to use and manipulate geographic objects to represent land resources and their interrelationships).

Virtual GIS Computer Laboratory

The virtual computer laboratory provided OC and DE students with 24 hour access to a secure, password protected learning environment consisting of GIS software (ArcGIS 8.3), MS Office Suite, GIS datasets, GIS assignments with step-by-step instructions and screenshots, and demo applications. The hardware of the lab was a Dell PowerEdge 6450/700 model with 4 x Genuine Intel 699 MHz processors, 4 x 73 GB hard drives, 4GB physical RAM, and total virtual memory of about 3 GB (adjustable based on user behavior). Currently up to 40 students can work simultaneously in the virtual computer lab. Students access the virtual computer lab using a Windows 2003 terminal server application through a web browser. Since students only need the Internet to access the virtual computer lab, no physical presence on-campus is required.

Such an implementation is ideal to teach GIS to DE students. Complex spatial GIS operations can be performed with the same speed in the virtual computer lab when compared to local computers. Benefits of the virtual computer lab are that students are not required to purchase expensive GIS software, no file transfer of huge GIS datasets via the Internet is required, and teaching assistants (TA) and the instructor have the ability to view students' results and provide real-time support for complex spatial operations. The implementation of a virtual computer lab is innovative and provides benefits to OC and DE students, TAs and the instructor. Technical support for the virtual computer lab was provided from the Institute of Food and Agricultural Sciences (IFAS) Information Technology (IT) and one TA taking care of login, upload, and other technical problems. Since students and the instructor did not get caught up in technical problems they could completely focus on the course content.

Survey

We conducted a survey to analyze various aspects of the course comparing the response of OC and DE students to the e-learning environment. In total 12 out of 16 DE students and 15 out of 18 OC students responded. The following questions were asked:

1. Were there any barriers to the success in the course? Possible answers provided to students: (a) Language skills; (b) Computer skills; (c) Learning disability; (d) Ability to manage time; (e) Others. (ranking 5: very high barrier, 4: high barrier, 3: medium barrier, 2: low barrier, 1: very low barrier).

2. Did you have any GIS knowledge prior to taking the course? Possible answers provided to students: (a) None; (b) Moderate; (c) Expert-knowledge.

3. Evaluate the increase of GIS knowledge at the end of the course. Possible answers provided to students included 5: very high, 4: high, 3: moderate, 2: low, 1: very low.

4. How useful were the following course materials for you: (a) PowerPoint slides; (b) Reading material (pdf format); (c) Additional resources (hyperlinks); (d) GIS assignments; (e) Online quizzes; (f) Support from TAs; (g) Self-reflective emails. (ranking 5: extremely useful, 4: very useful, 3: useful, 2: not very useful, 1: not useful at all)

5. How much time did you spend per week in the course? Possible answers provided to students: (a) 1-2 hours; (b) 2-5 hours; (c) 5-10 hours, (d) More than 10 hours.

6. How useful were the following interactive e-learning tools: (a) Event board which listed course

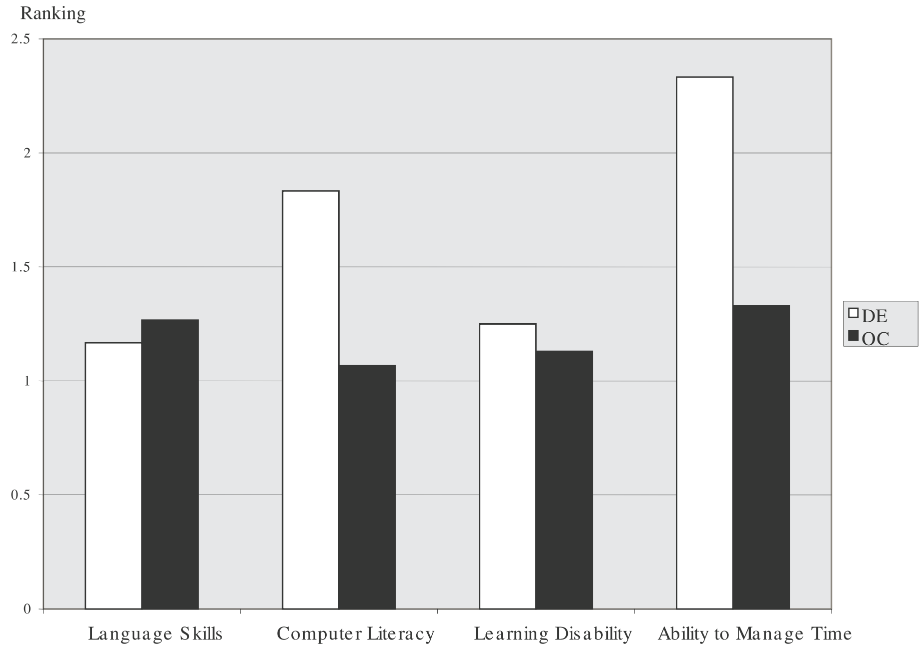

Figure 2. Students identified and ranked the barriers they were facing in the GIS course. (5: very high barrier, 4: high barrier, 3: medium barrier, 2: low barrier, 1: very low barrier; standard normal deviate (Z): -1.461 based on positive ranks; significance level: 0.144).

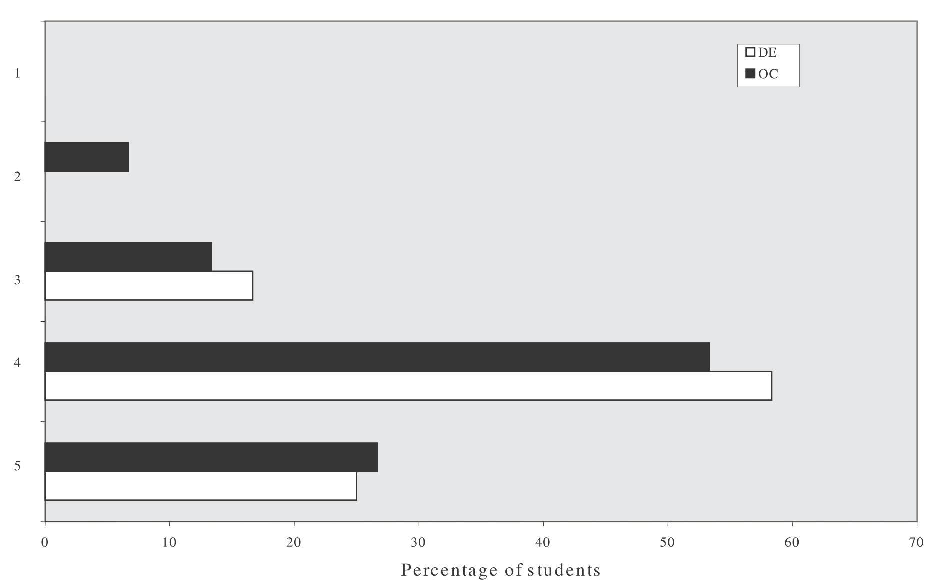

Figure 3: A self-assessment question asked students about the increase of GIS knowledge at the end of the course. (5: very high, 4: high, 3: medium, 2: low, 1: very low; standard normal deviate (Z): 0.0 (the sum of negative ranks equals the sum of positive ranks); significance level: 1.0).

announcements; (b) Message board which provided a framework for discussion between instructor, TAs and students; (c) Calendar which listed important class events; (d) Checklist which provided a list of tasks and assignments students needed to conduct in the course; (e) Online grade tool; (f) Online evaluation tool; (f) Histogram which provided information of individual performance in context of all other students; (g) Chatrooms which provided real-time communication between the instructor and students. (ranking 5: extremely useful, 4: very useful, 3: useful, 2: not very useful, 1: not useful at all).

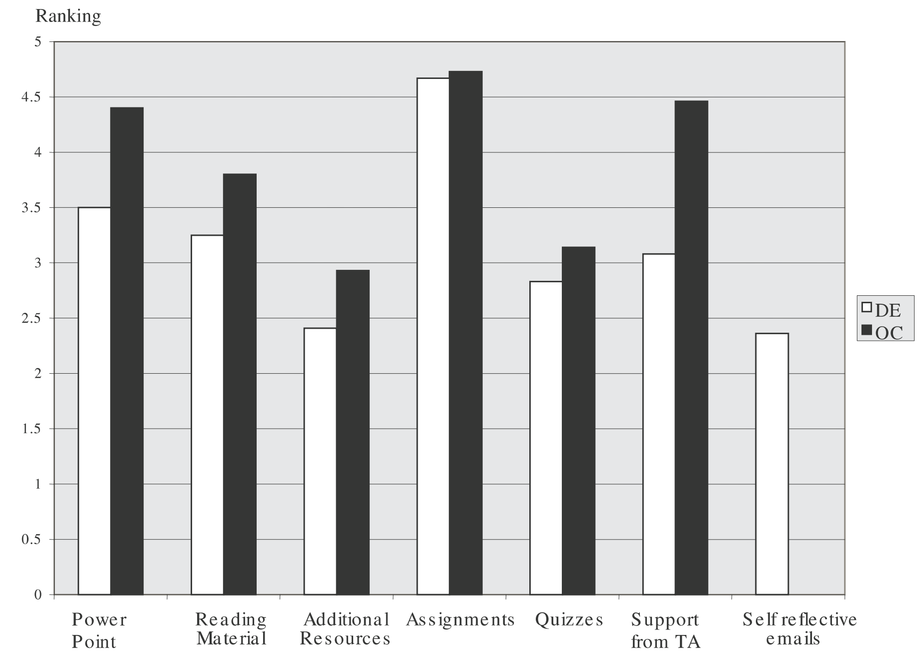

Figure 4: Students were asked to rank the usefulness of course material. The following tools were provided to students to evaluate (a) Power Point slides; (b) Reading material (pdf file format); (c) Additional resources (hyperlinks); (d) GIS assignments; (e) Online quizzes; (f) Support from TAs; (g) Self-reflective emails (Only DE students were encouraged to write self-reflective emails). (5: extremely useful, 4: very useful, 3: useful, 2: not very useful, 1: not useful at all; standard normal deviate (Z): -1.183 based on negative ranks; significance level: 0.237).

Results and Discussion

Results are summarized in Figures 2 to 5. We used the Wilcoxon rank sum test to test if the two independent samples (OC and DE response) come from populations having the same distribution. For the Wilcoxon test, the test statistics is the sum of the ranks in the first sample, and the distribution of this statistics under the null hypothesis does not depend on the distribution of the two populations. The test assumes all of the observations come from the same distribution that is symmetric about the true population mean. (Millard and Neerchal, 2001). If the significance level is large, the hypothesis that the response from OC and DE students has the same distribution is not rejected. On-campus and DE students' responded different when asked about barriers to succeed in this course. While OC students felt that they have high computer literacy DE students found it more difficult to manage their time (Figure 2). OC students had to attend fixed classroom hours (4 hours a week) whereas DE students were only required to participate in a 1-hour chatrooms once a week.

At the beginning of the course both groups of students had similar GIS knowledge. About half of both OC and DE students had none and moderate levels of knowledge. About 55% of OC students and 59% of DE students felt that their GIS knowledge increase was "high" and 27% of OC students and 25% of DE students thought that their GIS knowledge increase was "very high" (Figure 3). Differences in terms of GIS knowledge increase were insignificant between OC and DE students.

To evaluate the effectiveness of course material we asked students to rank on a scale from 1 to 5 the usefulness of the following materials: PowerPoint slides with notes, reading material, additional resources, GIS assignments, interactive quizzes, support from TA, and self-reflective emails. The OC students ranked TA support and GIS assignments highest while DE students ranked the PowerPoint slides and notes combined with GIS assignments highest (Figure 4). Both groups of students identified the hands-on assignments as highly valuable to learn about GIS applied to land resource management. We counted the instructor, students, and TAs emails to infer on DE and OC student activities. Based on email activity distance education students relied less on TA support than OC students. The opposite was true for the activity on the message board.

The self-reflective emails encouraged students to reflect on their progress and problems in the course. A higher percentage of female DE students (7 out of 8) versus male DE students (4 out of 7) submitted essays/notes to reflect on the progress in class and problems with course material. Male students responded with rather short notes whereas female DE students tended to elaborate on issues with the course. Each self-reflective email was commented on by the instructor promptly. This tool provided

Table 2. The time per week OC and DE students spent in the course.

Number of hours per week	Percentage of OC students	Percentage of DE students
1-2 hours	0	0
2-5 hours	6.7	16.7
5-10 hours	60.0	58.3
> 10 hours	33.3	25.0

(standard normal deviate (Z): 0.0 (the sum of negative ranks equals the sum of positive ranks); significance level: 1.0).

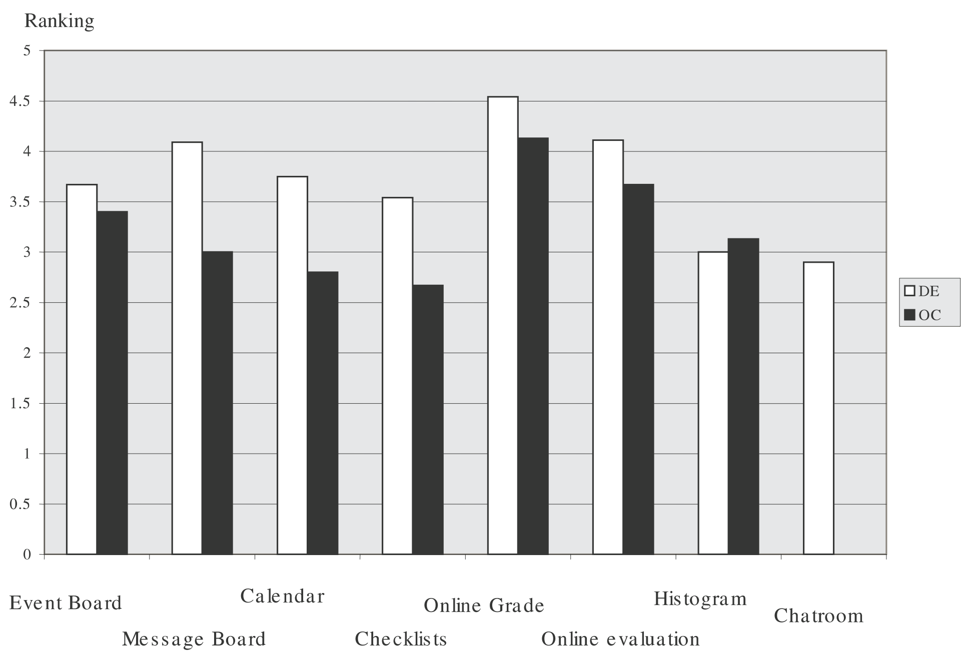

Figure 5: Students were asked to rank the usefulness of the following e-learning tools: (a) Event board which listed course announcements; (b) Message board which provided a framework for discussion between instructor, TAs and students; (c) Calendar which listed important class events; (d) Checklist which provided a list of tasks and assignments you needed to conduct in the course; (e) Online grade tool; (f) Online evaluation tool; (f) Histogram which provided information of individual performance in context of all other students; (g) Chatrooms which provided real-time communication between the instructor and students. (5: extremely useful, 4: very useful, 3: useful, 2: not very useful, 1: not useful at all; standard normal deviate (Z): -2.380 based on positive ranks; significance level: 0.017).

immediate feedback to the instructor as the course progressed. Students could share individual learning problems with the instructor within a protected environment receiving individual response from the instructor. Some DE students preferred such a “safe” communication tool in contrast to the global discussion tool provided at the message board where communication was shared by all students, the instructor and TAs. We tracked the messages posted on the message board to evaluate the activity of OC and DE students. Counting emails and messages is a simplistic approach to quantify the interaction between the instructor, TAs and students; yet it provides some information on student activity. Some students elaborated on topics and issues in their emails and notes posted on the message board while others were rather short. The quality of questions asked by students differed some students posted thoughtful questions while others asked questions about material covered in class or provided in form of reading material.

The virtual GIS environment enabled TAs and the instructor to work on the GIS assignments and projects within a secure e-learning environment. We were able to provide prompt support to students by viewing students' GIS files, folders and output. Overall, the OC students found it easier to use the virtual GIS computer lab since they had better computer literacy. In the first week of the course the OC students were introduced to the virtual GIS computer lab whereas DE students were introduced to the virtual GIS computer lab in the form of snapshots and text. More attention will be given to introduce the virtual GIS lab to DE students in the future using a digital movie format. Several DE students struggled in the beginning of the course with simple computer operations (e.g. browsing to folders, uploading of assignments) which were not directly related to GIS. This could be attributed to the lower self-reported computer literacy of DE students when compared to OC students. There were two TAs for the OC and two TAs for the DE section. Each TA spent in total about 13 hours/week tutoring students. Few DE students demanded much more support from TAs relative to other DE and OC students. The instructor time spent was invariant for teaching the OC and DE sections.

The number of hours per week spent to study course material was comparable between OC and DE students (Table 2). Several DE students pointed out facing time management problems due to over committing time to work or private activities. Whereas most OC students were full-time students seeking a graduate degree from the UF, most DE students had part-time or full-time jobs and family. Reasons for OC and DE to register for this course ranged from “continued education,” “seeking an academic degree,” “upgrading skills,” “no alternative options,” “schedule did not allow attending regular class” to “self-motivated.”

Distance education students experienced the interactive e-learning tools as more useful than OC students (Figure 5). The on-campus students had more personal interaction with the instructor and TAs in the form of lectures and the on-campus labs whereas DE students relied on asynchronous and synchronous e-tools. The activity on the DE message board was about six times higher than on the OC message board. Though DE students demanded close interaction with the instructor at the beginning of the course their participation in interactive activities was limited. For example, we offered two simultaneous chatroom sessions (chatroom 1: instructor and chatroom 2: TAs) each week. In average four students/chatroom used the opportunity to communicate with the instructor and TAs. Similarly, on the message board the main activity of questions, comments, and responses came from a core-group of DE students. Some students did not send self-reflective emails to the instructor. Other students did not respond well to the instructor's attempt to engage them in interactive course activities. A small group of DE students performed extremely well in graded activities without using the offered interactive e-tools suggesting that self-motivated students provided with e-material can learn as effectively as on-campus students. Our results are consistent with other studies. For example, Smith et al. (2003) identified “self-management of learning” and “comfort with e-learning” as the most important qualities for distance education students in a questionnaire administered to 107 undergraduate students.

In terms of graded learning outcomes we found no significant difference between OC and DE students based on a t-test. Our results are consistent with other studies which compared on-campus and online/distance education courses (Verduin, 1991; Wideman and Owston, 1991; Russell, 1999; Spooner et al., 1999; Swan, 2003). Duvall and Schwartz (2000) found no significant difference in academic performance between distance learners and their on-campus counterparts in a business course offered through a private university. Their study explored the relationship between academic performance and students' technological adeptness. Jain and Getis (2003) argued that Internet-based instruction in a physical geography course offered a viable alternative to traditional classroom teaching. They performed a matched-pairs experiment between OC and DE students and found no significant differences between groups in a post-test assessment. Similar findings were made in a study presented by Maki and Maki (2003) which compared learning outcomes and students' satisfaction in a web-based and lecture course. In our study we provided students not only with a course web-page but also made use of a virtual computer lab to closely mirror traditional on-campus GIS teaching. Such a virtual computer lab provided DE and OC students with the same framework to work on hands-on GIS assignments, learn the GIS software and work on a independent GIS project.

Face-to-face interaction was lacking in the virtual lab environment when compared to a traditional classroom setting. Questions from DE students were answered using asynchronous communication tools (e.g. email, phone) whereas OC students received immediate response to their questions in the classroom. DE students reflected on course material before asking questions whereas OC students asked many impulsive questions without consulting the provided course material (e.g. reading material). Browne (2003) reported on similar findings in a cyber-ethnography study focusing on a Masters Degree in Education. She found that asynchronous communication provided time for reflection and thoughtful formulation of questions and response. Mikropoulos et al. (1998) found that students' attitudes towards educational virtual environments mainly influenced the learning outcomes. Students with favorable attitudes towards virtual learning environments were more likely to improve learning when compared to students with negative attitudes. Batte et al. (2003) used two-way interactive compressed video course in agricultural economics and assessed students acceptance and performance. Results by Batte et al. (2003) also suggested that distance and “live” students performed equally in the same course.

Summary

Overall the interactive e-learning tools provided to DE students compensated for the lack of personal student-instructor interaction in the classroom and on-campus. Both groups felt that their knowledge in GIS had very much improved mainly due to the GIS assignments. The performance (grades) of DE and OC students were comparable. However, DE students indicated that they had to work hard to overcome barriers such as lacking computer skills and time management. The RLO environment was beneficial for the instructor to update course material and was well received by DE and OC students because of organizational clarity and transparency. A virtual GIS course has the potential to generate equal learning outcomes comparable to on-campus GIS courses provided students are self-motivated to study the course material and capable of managing their time.

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