

**Improving Geographic Knowledge Discovery and Spatial Reasoning with
Mobile and Web-based Geographical Information Systems**

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Abstract

Over the last decade, a dramatic rise in the availability of Internet mapping services, such as Google Earth, has allowed users to overlay and display geographic data, increasing geographic knowledge discovery. Very noteworthy is the recent deployment of these mapping services onto mobile devices, such as Global Positioning Systems (GPS) and I-phones, allowing one to hold computing power in the palm of one's hand, offering the possibility of delivering location-dependent information. However, most mobile applications have limited functionality, restricted to location mapping and data collection.

Our research objective is to advance geographic knowledge discovery and to foster spatial reasoning through mobile geographic education. Specifically, we propose to design and develop a suite of web-based Geographical Information Systems (GIS) tools, deployable through wireless technology on mobile devices equipped with GPS units. Location-dependent functionality on mobile devices will encompass functions stimulating active learning processes through in-field experiments, such as overlay analysis, line-of-sight between points and viewshed analysis, proximity analysis, computation of service areas and combining spatial and attribute queries. Our second objective is to demonstrate that the integration of mobile technology in GIS-related courses facilitates collective learning experience.

Access to this technology will enable students to use Internet mapping in dynamic and interactive ways to engage them in generating hypotheses, formulating spatial relationships, ultimately advancing geographic knowledge discovery. Most importantly, the proposed mobile computing technologies will allow teachers to bring the classroom into the field. This technology will be incorporated as in-situ laboratory exercises in five introductory GIS courses, and on-site workshops.

Budget Request for SOTL Grant

Year 2011

Joint Proposal? **X** Yes No

Title of Project Improving Geographic Knowledge Discovery and Spatial Reasoning with Mobile and Web-based Geographical Information Systems

Duration of Project 12 months

Primary Investigator(s) Dr. Eric Delmelle, Dr. Wenwu tang, Ms. Laurie Garo

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UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates) none

Allocate operating budget to Department of Geography

		Year One
Account #	Award	January to June
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	\$2500
911250	Graduate Student Salaries	\$10800
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel – Domestic (3conferences)	\$3000

926000	Travel - Foreign	
928000	Communication and/or Printing	
930000	Supplies	
942000	Computing Equipment (8 handheld devices, 8 USB GPS, 2 servers)	\$8472
944000	Educational Equipment	
951000	Other Current Services	
GRAND TOTAL		\$24772

Attachments:

1. Attach/provide a narrative that explains how the funds requested will be used.

Two graduate students will be hired to work directly under the supervision of the PIs during the Spring 2011 (15 weeks) and one of the graduate student will work during the summer 2011 (6 weeks), both at a rate of \$15/hour, at 20 hours a week.

The requested computing equipment consists of eight iPad handheld devices of 32GB of RAM each (\$599/unit, total = \$4792). We used (http://store.apple.com/us/browse/home/shop_ipad/family/ipad) to estimate handheld its price. GPS prices are based on USB Garmin GPS, around \$85/unit (total = \$680). (<https://buy.garmin.com/shop/shop.do?pID=27594&ra=true>). Six out of the eight handheld devices and USB GPS will be used for production, while two will be kept for backup and testing. We also request two computer servers at \$1500/unit with two monitors (total: \$3000), 1 server for production, one server for backup and testing (<http://www.its.uncc.edu/Desktop/hardware/computers/index.html>).

The faculty stipend will support Eric Delmelle during the Summer of 2011 to develop assessment tools and new laboratory exercises. The domestic travel funds will be used by Dr. Eric Delmelle. Dr. Wenwu Tang and Ms. Laurie Garo to dissemination the results of the proposed technology at academic conferences.

2. Has funding for the project been requested from other sources? ___ Yes ___X___ No. If yes, list sources.



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October 28, 2010
SOTL Grants Committee
Center for Teaching & Learning
ctl@uncc.edu

Dear Committee Members:

Please accept this letter of support for the SOTL proposal, “Improving Geographic Knowledge Discovery and Spatial Reasoning with Mobile and Web-based Geographical Information Systems.” The proposal is being submitted by Eric Delmelle, Wenwu Tang, and Laurie Garo of the Department of Geography and Earth Sciences. These investigators seek support to develop a suite of web-based tools for Geographic Information Systems. These tools will be available to students in a variety of the Department’s courses dealing with GIS and will be deployed wirelessly to handheld devices. The goal is to provide students with a better understanding of GIS functions and principles by using Internet mapping in dynamic and interactive ways.

The proposal builds in appropriate assessment methods as well as a plan to disseminate the results beyond campus through conference presentations and possible publications. Another interesting feature of the proposal is that the team will incorporate GIS data from our own campus for the exercises they are developing. The PIs also hope that they will be able to leverage results from the early implementation of the project to apply for a National Science Foundation Course, Curriculum and Laboratory Improvement (CCLI) Grant. Moreover, it seems to me that, as handheld computing devices become more widely available and more affordable, the technology required for this innovation will be sustainable over the long term.

In short, the aims of this proposal are completely in tune with our College strategic goals regarding curricular innovation, the use of cutting edge technology for instruction, and increasing external funding. It is my pleasure to recommend the proposal for your consideration. Please let me know if you require further information. Thank you.

Sincerely yours,

Nancy A. Gutierrez, Dean
College of Liberal Arts and Sciences

Project Narrative

A. Specific Aims

Geospatial technology is one of the top eight industries identified by the White House and the U.S. Department of Labor in 2006 as a rapidly growing job market, and Geographic Information Systems (GIS) has been considered as one of the fastest growing technological field. The Department of Geography and Earth Sciences at UNC-Charlotte has a long tradition of offering a suite of GIS courses at various technical levels, while a broad palette of applied courses complement those offerings (e.g. environmental modeling with GIS). For 2010 alone, more than 150 students were enrolled in GIS technical courses (GEOG 2103 - Elements of GIS and Technology, GEOG 4120-Fundamentals of GIS and GEOG 4000 – GIS for non-majors), while a large quantity of students registered for applied GIS courses. GEOG2103 serves as a requirement for GEOG4/5120 (Fundamentals of GIS), allowing students to advance to higher level and applied GIS courses.

In these courses, the majority of the time is dedicated to the learning of GIS tools and functionality within the software environment through simulated case studies coupled with synthetic or real data. Examples of functionality include overlay analysis, which allows the superimposition of geospatial layers, facilitating the identification of spatial relationships (e.g. incidence of cancer cases and proximity to brown fields in spatial epidemiology, or concentration of 911-calls and socio-economic information in crime mapping). Other typical GIS functionalities which foster spatial reasoning and knowledge discovery include (1) buffer analysis and the delineation of service area, for instance to find on-campus emergency phones within a range of two minutes travel-time from a particular location, and (2) line-of-sight between two locations using elevation and buildings as barriers.

Need for mobile-based geographic education

Geographical and environmental sciences have a long history of incorporating field observations into teaching and research. The last forty years have brought far reaching changes in the way field data is collected with the advance of remote sensing and Global Positioning Systems (GPS) technologies (Nusser et al. 2003), while emerging mobile computing devices such as PDAs have the ability to sense their locations. It is expected that these mobile computing devices will have an increasingly significant impact on our daily lives. Consequently it is critical that GIScience students understand the strength and weakness of this emerging technology. Concurrent to these recent technological improvements on mobile devices, universities have invested tremendous efforts in delivering wireless access on their campuses, yet the technology is mostly

used for intra-building applications and rarely exploited for outdoor educational activities.

Recent improvements in internet accessibility underline the importance of revising technological-based curriculum, such as GIS, especially when this technology is used to understand complex spatial and temporal processes. Although geographic knowledge and spatial reasoning can be nurtured in a traditional classroom setting, abstract concepts remain difficult to grasp. Field work provides an alternate setting to promote understanding through discovery, but such trips are limited to a particular place and time, and answers to questions which may arise during these experiments addressed afterwards. Such interruptions in the learning process limit students' ability to understand complex processes. Mobile technology can enhance the shift from pure instructor centered classroom teaching (formalized context in Figure 1) to constructivist learner centered educational settings (Holzinger et al. 2005), supporting the independent formation of knowledge by exploration (physical and informal contexts in Figure 1).

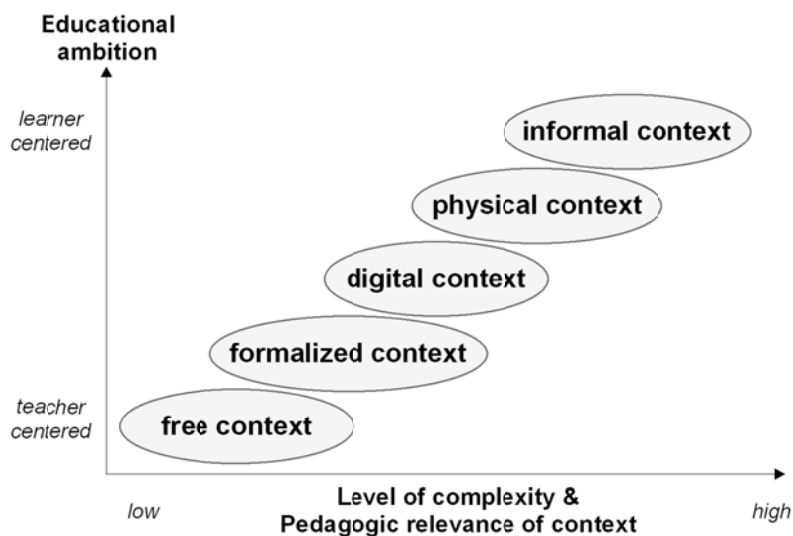


Figure 1: Categories for mobile-learning (after Frohberg 2006)

Arguably, the single greatest intellectual force and competitive advantage in the 21st century is the rapid assimilation of new knowledge to fuel innovation. Our students will gain cutting-edge skills through access to new mobile-based mapping technologies. This new, innovative use of existing GIS technology will be embedded in the GIS courses at UNC-Charlotte in the form of in-field experiments.

Impact of the proposed study on teaching activities:

Approximately 150 students from geography, earth science, engineering, biology, public health, public administration, business, anthropology, sociology, criminal justice will directly benefit from the proposed technology. We expect an increase in enrollment in three introductory GIS courses (GEOG 2103 -Elements of GIS and Technology, GEOG 4/5120 -Fundamentals of GIS and GEOG 4/5000- GIS for non-majors). In addition to anticipated increased enrollment in those courses, we expect that the proposed technology will:

- Generate exciting teaching material through the use of active learning techniques that enable students to practically apply theories, practice concepts and techniques, and receive answers to spatial questions using web communications.
- Result in student learning outcomes that include the ability to rapidly browse, display, query, and interact with digital geographic data and information through a mobile computing device.
- Ease the dissemination and understanding of GIS concepts, benefitting the self-development of geographic knowledge discovery and spatial reasoning through in-field experiments.
- In-field experiments are also expected to increase instructor-student interactions.
- Increased visibility of UNC-Charlotte's Department of Geography & Earth Sciences as a leader in the teaching of geospatial sciences.
- Enhanced small group learning environments through small group experiments

How the proposed activity fits within the Geography and Earth Sciences mission:

Incorporating the proposed technology in our GIS course offerings fits two critical missions of Department of Geography and Earth Sciences: (1) to maintain high quality undergraduate programming in order to prepare students for professional careers and/or further graduate study, and (2) to provide skill-building that prepares students for productive careers and responsible citizenship. In addition, one of the five main themes of the department is geospatial perspective which encompasses geospatial information systems and technology. We expect that synergistic advances in GIS, data collection and mobile computing will have far-reaching effects in academia, and spatial science in particular. Finally, activities built around the proposed technology will increase the visibility of our department around campus and at the national level.

B. Literature Review

The proposed mobile and Web-based GIS in this project benefits from the advancement of distributed GIS (see Peng and Tsou 2003). Conventional GIS rely on desktop computing environments to access, analyze, and visualize geographically referenced data (Goodchild 1992; Worboys and Duckham 2004). The rapid development of Internet and Web technologies enables GIS operations (e.g., access, analysis, and visualization) of geographic data in a decentralized manner (Peng and Tsou 2003; Armstrong and Bennett 2005). Internet allows multiple GIS users to conduct, either individually or collaboratively, GIS operations on data maintained in remote computer servers; Web techniques provide cross-platform interfaces to support these Internet-based GIS operations, often encapsulated as web services (Foster 2005; Singh and Huhns 2005). As the recent emergence of cyberinfrastructure technologies (NSF 2007), the power of Internet-based GIS in facilitating decentralized GIS operations has been increasingly acknowledged. Standards (e.g., Open GIS standards; see <http://www.opengeospatial.org/standards>) for the set of geospatial web services have been maturely developed. In particular, these standards are supported by most commercial and open-source Web GIS software packages, represented by ArcGIS server (<http://www.esri.com/software/arcgis/arcgisserver/>) and GeoServer (<http://geoserver.org>), thus greatly facilitating distributed GIS operations. Further, the advance of mobile (or ubiquitous) computing techniques (e.g., personal handhelds, cell phones, and wireless networks) motivates researchers and educators to explore the utility of Web-based GIS within mobile computing environments (Clarke 2004; Tsou 2004; Armstrong and Bennett 2005). However, this exploration effort lags far behind the development of mobile computing techniques.

C. Methods

We propose to develop a mobile and Web-based GIS to improve the teaching and learning of fundamental GIS knowledge. Figure 2 illustrates the design of our system, including server- and client-side sub-systems. The server-side sub-system will maintain and process GIS data, and respond to client-side requests for GIS analysis. Student information for specific courses will be maintained on the server side. A GIS web server, supported by a generic web server (e.g., Apache Tomcat; see <http://tomcat.apache.org>), will be established to provide geospatial web services, including web mapping, that update data in GIS database dynamically. On the client side, students will be organized into different groups each assigned with a GPS-enabled handheld unit. Each student group as a team will be given a specific task (e.g., GIS data collection, spatial analysis)

and, most importantly, students will learn specific GIS concepts/methods as they complete their tasks in the field.

Software and hardware

We will use open-source GIS and database software to implement our system, capitalizing on GeoServer (<http://geoserver.org>) as the GIS web server (enabled by Apache Tomcat). Commercial GIS software, ESRI ArcGIS will be also used (as needed) to support GIS operations and spatial analysis. The database software that we will use is PostgreSQL (<http://www.postgresql.org>) and its spatial database extension, PostGIS.

To make this proposed GIS functionality and GIS data available on the internet, the PIs will be assisted by two graduate students with web-based programming skills and background in GIS.

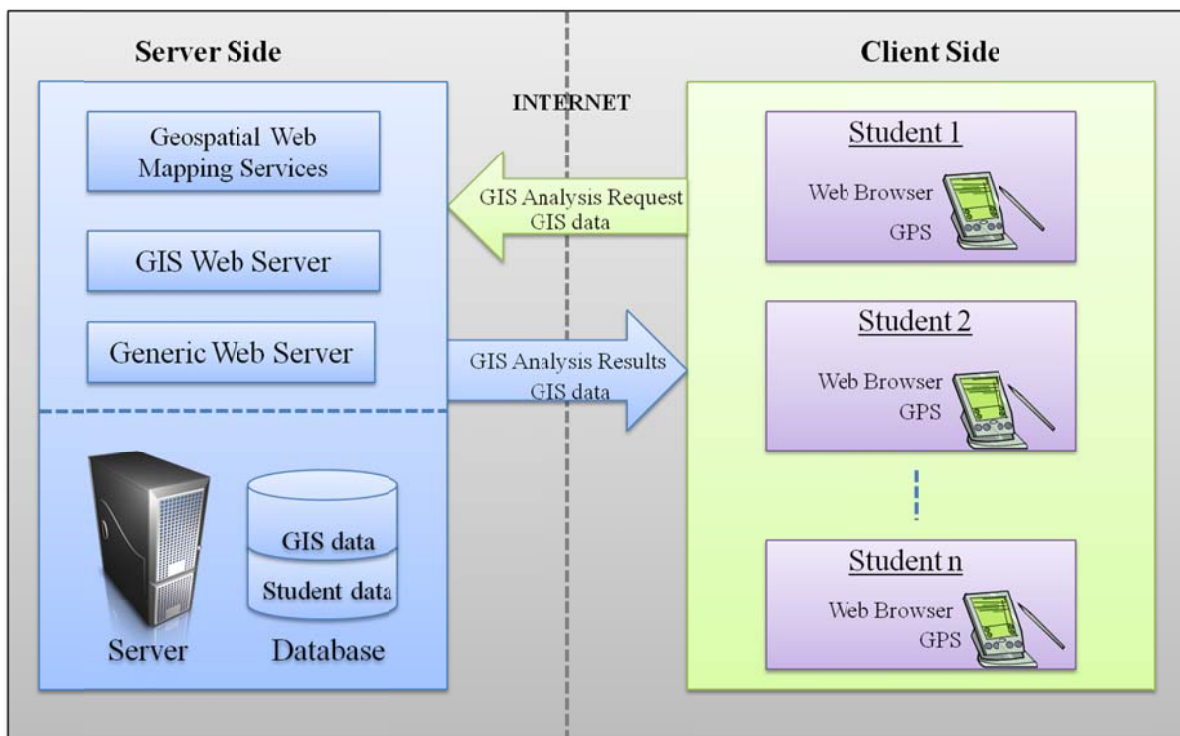


Figure 2: structure of the proposed Mobile and Web Geographic Information system (including server- and client-side sub-systems)

We plan to use two computer servers as computing support on the server side (see Figure 2). One of the computer servers will provide geospatial web services and database operations in a production mode; the other one will be used to backup the first server to ensure the robustness of our proposed system. On the client side, handhelds (e.g., IPAD) will be equipped with GPS units (e.g., through USB interfaces) and

connected to Internet via wireless networks. Handheld devices will have multimedia support, including microphone and/or video camera, that allows students to communicate with each other or with instructors.

GIS data

A set of GIS data from the UNC-Charlotte campus will be used for the new in-field exercises. The PIs have built an extensive collaboration with Facility and Management, which houses campus information in digital format, for instance building footprints, walkways, vegetation, terrain, transportation infrastructure, and blue phone locations to cite a few.

Proposed GIS functionality

The web-based delivery of GIS functions from mobile computing devices offer the students an interactive environment where several relevant GIS operations will be replicated. We intend to develop a set of internet-based GIS functions, which are organized in two groups of complexity and functionality (see Table 1). These functions are inherently associated with fundamental GIS concepts and methods. Thus, the implementation of these functions in our proposed Mobile and Web GIS is necessary and will greatly enhance the learning of associated GIS knowledge.

<i>Group 1: Introductory GIS functionality</i>	<i>Group 2: Intermediate GIS functionality</i>
<ul style="list-style-type: none"> • GPS data collection • Real-time mapping • Overlay analysis • Mapping at different scales 	<ul style="list-style-type: none"> • Proximity analysis (buffering and service area) • Line-of-sight and viewshed analysis • Spatial and attribute queries • Shortest path

Table 1. Set of Internet-based GIS functions to be implemented in the proposed Mobile and Web GIS.

As an illustrative example, Figure 3a shows the proximity analysis function using the campus pedestrian network while figure 3b displays the line-of-sight between the green house and the student union, where the green section of the line is visible and the red section is not. Those maps were made within a desktop computing environment. With the proposed technology, such functionality would directly be available on a mobile computing device. This dataset (pedestrian network, building location, and elevation) is made accessible through the mash-up of web mapping services provisioned by the server. Alternatively stated, the GIS data and GIS functionality are published on the internet through a server, which can be accessed and used in real-time from a mobile device. Access to this GIS functionality on the field will facilitate the understanding of GIS concepts and collaborative learning.

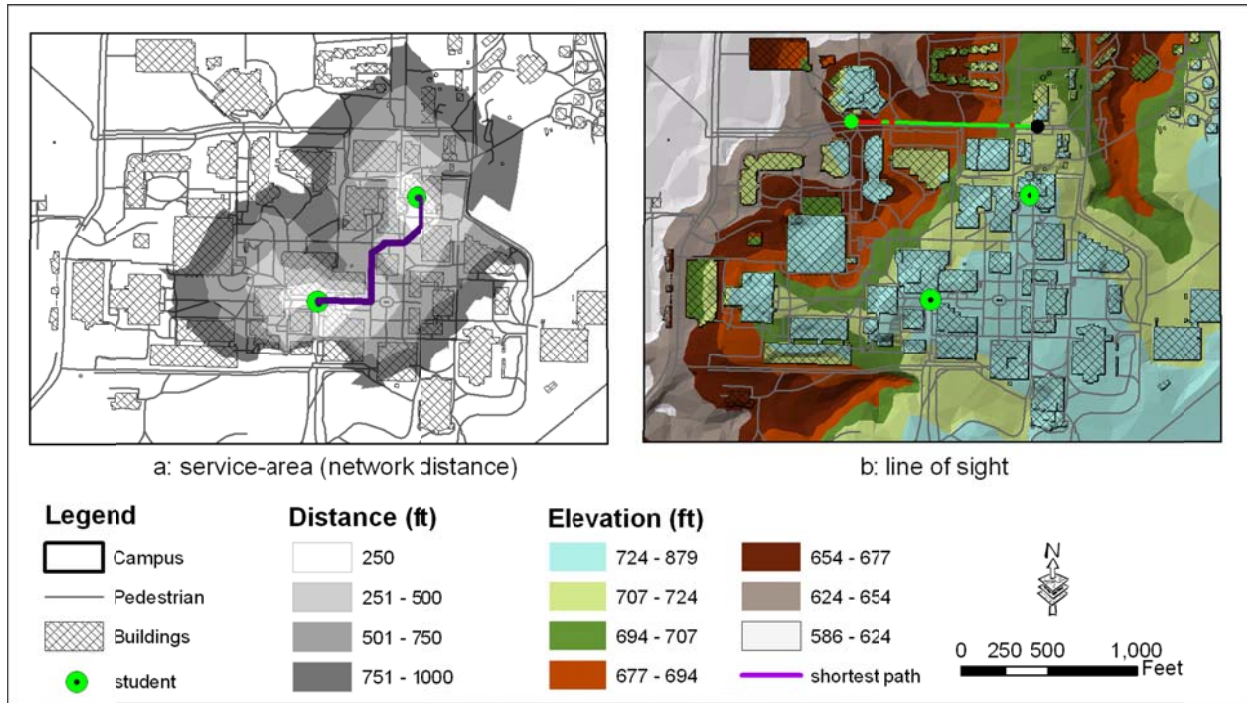


Figure 3: (a) application of the service area proximity analysis and shortest path determination; (b) the line-of-sight procedure, using campus GIS data.

Development of new laboratory exercises.

The Mobile and Web based GIS will facilitate improved student understanding of fundamental concepts and techniques taught in the introductory level courses. There will be lectures in this state of the art method of data collection, analysis and mapping. Two laboratory exercises using group 1 functionality will be modified to both GEOG 2103 (Elements of GIS technology) and GEOG 4000 (GIS for non-majors). These labs will encompass field based learning afforded by the technology. Concepts of scale and measurement, data collection and real time verification, utility of vector and raster based formats, and theme-based spatial queries are a few of the lab modifications. Similarly, two existing labs will be modified in GEOG 4120 (Fundamentals of GIS) with a concentration on group 2 functionality, along with the addition of a new lab. A workshop will also be given in the GIS seminar (GEOG4800). To accommodate large groups of students, these labs will be scheduled for maximum student availability. Students for each class will be grouped into teams each having a handheld device with GPS. A course of 30 students for instance would be divided into 6 groups of 5 students, thus requiring 6 handheld devices, with an additional 2 devices for backup.

D. Evaluation

By using the proposed web-based functionality on mobile computing devices, students will improve their understanding of several key GIS concepts, exhibiting a stronger

dexterity at problem solving. We intend to incorporate both formative and summative assessment methods to determine improved learning outcomes and increased student engagement in GIS coursework. A formative evaluation will consist of a pre-test to indicate baseline knowledge obtained in prerequisite coursework and GIS courses taught prior to the start of this project. In the summative evaluation, students will complete a post test and survey questionnaire to gauge learning effectiveness relative to the pre test, and overall assessment of the course curriculum and technology for learning GIS.

Each lab exercise will contain questions that students answer to demonstrate learning as per relevant objectives, with rubrics indicating points per expected outcome. Evaluative surveys will be completed by students twice each semester. The surveys will offer students the opportunity to evaluate the effectiveness of the technology and related curricula in helping them understand concepts, learn techniques, and observe patterns and relationships at midterm and end of semester. Students will also be asked to indicate how effectively the project technology and activities engages students in active learning and increases student interest in GIS. Results will be tabulated and graphed for comparison as the semester progresses. A comparison will be made between pre and post test results to determine the percentage of students who increased their learning by a specified amount.

Finally, we will monitor (1) enrollment figures in GIS-related courses, especially for introductory courses, (2) variation in diversity of students in classes (major and standings), which will indicate whether the proposed technology has the potential to reach other disciplines.

E. Knowledge Dissemination

Project results will be presented at the *Annual Meeting of the University Consortium for Geographical Information Science*, the *Association of American Geographers Annual Conference*, and the *ESRI Education User Conference*. We will also disseminate findings from the proposed technology through on-campus presentations, and will seek publications in international outlets such as the *Journal of Geography in Higher Education*, as well as the *Professional Geographer*.

F. Human Subjects

We expect this project to be exempt from IRB approval as per Policy Statement #63 – III: “Small research projects conducted primarily for instructional purposes within the context of a formal class, and not designed to contribute to generalizable knowledge, may not require review by the IRB, provided the instructor is prepared to accept

professional and ethical responsibility for all research projects conducted in conjunction with the class”.

G. Extramural Funding to Sustain the Proposed Technology

The proposed technology will serve as the core of a cyberinfrastructure-enabled GIS framework that supports GIS operations and spatial analysis via Internet. Based on the proposed technology, we will continue on developing such a GIS framework to facilitate the education and research of advanced GIS. We will work hard to secure external and/or internal funding to sustain the developed technology and update equipments. The PIs will leverage findings from the proposed technology by applying for a National Science Foundation Course, curriculum and Laboratory Improvement (CCLI) Grant. Two of the PIs have applied in the past to this program.

H. Timeline

January - May 2011: Design and development of a prototype mobile and Web GIS

- Design of hardware and software specifics for mobile and Web GIS (D, T)
- Purchase required hardware, including GPS, handhelds, and computer servers (D, T, G)
- Compilation of necessary GIS datasets for new labs (D, G) and design of tasks to be performed during in-situ experiments (D, T, G)
- Configuration and testing of hardware and wireless internet (T, Gr. S.)
- Installation of software for clients and servers (T, Gr. S.)
- Development of a prototype mobile and Web GIS (T, Gr. S.)

June - August 2011: Development of the mobile and Web GIS

- Development of the client-side software (T, Gr. S.)
- Development of the server-side software, including web server and database (D, T, Gr. S.)
- Integration of client- and server-side software (T, Gr. S.)
- Dry-run testing of the proposed technology (D, T, G, Gr.S.)
- Development of survey questionnaires to evaluation of technology (D, T, G)

September - December 2011: Implementation and evaluation of the mobile and Web GIS

- Evaluation of the integrated mobile and Web GIS in the following classes (D, T, G, Gr. S.)

GEOG 2103: Intro to GIScience & Technologies

GEOG 4/5000: GIS for Non Majors

GEOG 4/5120: Fundamentals of GIS

GEOG 4/5800: GIS Seminar I (as a workshop)

- Collection of feedback from students and instructors (D, T, G)
- Tuning of the mobile and Web GIS (D, T, Gr. S.)
- Documentation of the complete mobile and Web GIS (D, T, G)

D: Eric Delmelle T: Wenwu Tang G: Laurie Garo Gr.S.: Graduate Students

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