Exposing Agriculture Students to GPS/GIS: Strategies, Outcomes, New Directions

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Abstract

Global positioning system (GPS) and geographic information system (GIS) technology are important tools in the emerging agricultural revolution called precision agricultural or site-specific management. Many students and faculty of agricultural colleges have little exposure to or experience with these new technologies. This paper summarizes how GPS/GIS instruction was incorporated into an existing agriculture curriculum and presents the perspectives of participating faculty following implementation of the project. Faculty from five departments received training in basic GPS/GIS procedures through a series of workshops, seminars and roundtable discussions. Coordinated lesson plans were developed and GPS/GIS modules containing basic information were incorporated into three lower division courses. More advanced discipline-based GPS/GIS lab experiences were implemented in eight upper division courses. Benefits to students cited by faculty included increased awareness of GPS/GIS agriculture applications, improved ability to operate GPS/GIS equipment and improved employability of students. Several obstacles to increased implementation of the project were also expressed by participating faculty. These included lack of GPS/GIS equipment, courses which were already 'content crowded', and students receiving similar GPS/GIS information in lower division courses and/or lacking certain prerequisites in upper division courses.

Introduction

One of the most rapidly developing technologies in the agricultural sciences is site-specific management or precision agriculture. Precision agriculture can be described as the application of a holistic management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with agricultural production, marketing, finance, and personnel (Olsen, 1998). Advanced computer systems that use geographic information system (GIS) and global positioning system (GPS) software, remote sensing, and information analysis are changing the way natural resource managers and agricultural producers conduct business. Recent surveys show that adoption of precision agriculture practices by producers are increasing and that the infrastructure services necessary to support these early adopters is developing (Khanna et al., 1998; Olsen, 1998). The demand for personnel broadly trained in the agricultural and natural resource management applications of GPS/GIS technology is forecast to grow (Parker, 1991). Many people using GPS and GIS in the mid 1980's through early 1990's received their training by means of either software vendor workshops or on-the-job training (Morgan, 1987; Righetti, 1997). The emphasis has been on training as compared to education. Education seeks to enable students to understand basic concepts, principles and theories while training strives to make the trainee proficient in using the functions of a particular tool, for example, a specific GIS software system (Burns and Henderson, 1989). As technology is continually changing, there will always be a need for retraining practicing professionals. However, in the long-term it is the responsibility of the university system to educate future agricultural and natural resource professionals and prepare them for the demands of the rapidly changing workplace. The opportunities for site-specific management of plants, soils, rangelands, livestock, and pests are innumerable. However, most undergraduate students of agriculture and land resource science have little, if any, experience with the GPS and GIS technologies that provide these new opportunities.

Background

Prior to this project, access of agriculture students at Montana State University to GIS instruction was limited to two courses, Geography 305, Introduction to Geographic Information Systems and Geography 411, Advanced Geographic Information Systems and Geographic Analysis offered through the Department of Earth Sciences. These courses did little to address agricultural applications of GIS and there were no course offerings providing students with GPS instruction. Departments within most colleges add new courses to existing curricula to provide students with exposure to a new body of knowledge or technology. The approach of this project was to address a method for integrating a new technology that impacts many courses within a broad college curriculum. Beginning in fall 1996 a USDA-funded Higher Education Challenge Grant was implemented to incorporate GPS/GIS technology across a broad undergraduate curriculum in the College of Agriculture at Montana State University. The objectives of the grant included: 1) training local and regional faculty in fundamental concepts of GPS/GIS principles and use, 2) development of GPS/GIS instructional modules for agriculture and land resource science courses, and 3) development and implementation of experiential learning opportunities with GPS/GIS-based site specific management. This article provides an overview of how GPS/GIS instruction was incorporated into the existing College of Agriculture curriculum at Montana State University and presents the perspectives of participating faculty, including the advantages and pitfalls of the process, following implementation of the four-year project.

Methods

Our approach was to develop and incorporate basic or core GPS/GIS instructional elements within the required lower division courses PSES 201, Soil Resource Management and ARNR 101/102, Principles of Rangeland Management. In addition, GPS/GIS applications specific to several disciplines within the college such as weed ecology or nursery management were also developed and incorporated into the courses. The upper division courses generally have lower enrollment and would allow for more intensive hands-on instruction. In this manner, most of the students within the College of Agriculture would be exposed to the core GPS/GIS information in lower division required courses that served as prerequisites to many of the upper division courses in the college; the modified upper division courses containing GPS/GIS modules would then provide discipline-specific applications of the technology.

The project began with faculty training followed by development and implementation of general and discipline-specific GPS/GIS modules. Participating faculty represented five departments and had varying degrees of exposure to GPS/GIS technology. Workshops, seminars and roundtable discussions focused on GPS/GIS theory, operation, applications, as well as approaches to incorporating the technology into classroom and laboratory instruction. Seven GPS and GIS seminars and workshops held in the first few months of the grant provided participating faculty with basic skills and knowledge of the technology. In addition, these meetings provided opportunities to discuss how GPS/GIS technology impacts various agricultural disciplines and how learning objectives might be added to the lectures and labs of selected courses. In February 1996, a workshop series entitled “GPS Applications in Agriculture” covered topics including GPS fundamentals, differential correction, display of GPS data in a GIS, difference between high and low precision mapping, and agricultural applications of GPS and GIS. Additional seminars addressed weed distribution and spatial dynamics. In April, faculty were introduced to a basic GIS called MAPS Atlas, which has 150 land and climate attributes for the state of Montana. Once the faculty had established a basic level of knowledge with the technologies, a workshop trained them in the use of GPS receivers and GPS and GIS software.

During June 1996, faculty meetings focused on the development of outlines for course instructional modules they would use in their classes. In order to establish a common core of information for faculty use, a set of slides and transparencies was developed for use in GPS lectures. The slide set was a PowerPoint presentation that addressed a basic overview of GPS, GPS applications, differential GPS, advanced GPS concepts and GPS/GIS mapping issues. The slide set could be used as a stand-alone introduction to GPS technology, or as part of a more extensive lesson plan that included GPS receiver demonstrations, for example. This slide set, along with the experiential learning modules tailored by faculty for applications in their field of study, provided the basis for GPS/GIS education in College of Agriculture courses. Faculty began to incorporate GIS and GPS lectures and modules into their courses between the spring of 1996 and fall of 1997. A total of eleven courses in the departments of Animal and Range Sciences and Plant, Soils and Environmental

Sciences were modified to include GPS/GIS educational objectives (Table 1).

Evaluation

Faculty and staff participating in the "GPS Applications in Agriculture" workshop completed evaluations following the training sessions (data not shown). In addition, faculty participating in the project completed exit surveys within 3 months of the project conclusion. The exit survey and survey results are presented in Table 2.

Results and Discussion

Twelve faculty initially expressed interest in the project and committed to participate in training and GPS/GIS lecture/lab development, based on their course needs. The initial training phase of the project was successful in providing faculty with basic information and ideas relative to instructional development. Nineteen faculty and staff participated in a GPS Applications in Agriculture workshop conducted at the early stages of the project (1997) consisting of two sessions aimed at providing basic GPS knowledge and skills to the participants. Overall, participants evaluated both sessions of the workshop very highly. Seventy-nine percent of participants indicated that the workshop increased their knowledge 'a great deal', with only 16% and 5% of participants indicated their knowledge had increased 'a fair amount' or 'a little', respectively. All components of the workshop that were rated scored 4 or 5 on a 1-5 scale, with 5 being excellent. The next phase of the project involved the development and implementation of GPS/GIS lectures and labs. An underlying goal was to provide students with basic core information in lower division courses and more advanced GPS/GIS application opportunities related to specific disciplines in the upper division courses. These upper division courses would have lower division courses containing the GPS/GIS core information as prerequisites. This structuring of the content through the curriculum proved somewhat problematic. Some students experienced repetition in classes containing 'core' GPS/GIS modules, while others found themselves in upper division courses being exposed to more advanced GPS/GIS application exercises without having exposure to key concepts from lower division courses. This raises the question of incorporating material into a curriculum that is not entirely vertically integrated. The problem of redundancy or lack of prerequisites can be compounded when students do not follow an established course sequence.

Table 1. Montana State University College of Agriculture Courses Incorporating GPS/GIS Content

Course Number	Course Name	GPS/GIS Content
ARNR 101/102	Principles of Rangeland Management	Mapping field exercise introduced students to GPS. MAPS Atlas GIS was used to demonstrate major vegetation types in Montana.
ARNR 353	Rangeland Resource Management	Students learned general GPS/GIS principles from lecture and Internet-based instruction.
ARNR 453	Rangeland Resource Measurements	Students learned GPS fundamentals and coordinate systems as they apply to collecting range data. Students mapped weed-infested and burned areas on a ranch.
ARNR 460	Soil Remediation and Overburden	Students learned GPS fundamentals and participated in exercise demonstrating how to use GPS receivers, then visited a working ranch where they mapped management areas.
ARNR 463	Principles of Natural Resource Rehabilitation	Basic GPS/GIS principles taught using Internet slide set. Students learned to use GPS units by practicing on campus, then mapping a burned area on a local ranch.
PSES 201	Soil Resource Management	MAPS Atlas exercise evaluated students ability to gather information about soil forming factors from a GIS.
PSES 357	GPS Fundamentals and Applications in Mapping	Students learned GPS fundamentals and participated in GPS team and individual projects. Students exported their GPS data into a GIS and created a presentation quality map.
PSES 417	Remote Sensing	Students used GPS and aerial photos in a campus mapping exercise.
PSES 435	Nursery Management	Students learned basic GIS concepts using MAPS Atlas and created maps depicting low, medium and high production potential for nursery crops in Montana.
PSES 451	Soils Field Course	GPS receivers used by students to locate and characterize environmental conditions for several sites. Aspect, slope, wind direction, relative wind speed, and geology were recorded with data logging software to determine causes and degree of soil formation.
PSES 454	Soil Classification	Students used GPS receivers to map and record soil formation data for four soil pits within three distinct geologic zones. Each student submitted a report contrasting the three geologic zones based on GIS map displaying their georeferenced soils data.

The extent to which faculty implemented GIS/GPS content into their courses varied considerably. Some faculty developed and implemented hands-on GPS activities at working farms in conjunction with several lectures while others incorporated no GPS activities in their labs. A number of barriers to adoption of technology in the classroom exist among faculty, including conservatism and commitment to traditional teaching methods (Albright and Graf, 1992). To understand more about the perspectives of participating faculty, a survey was conducted upon completion of the project (Table 2).

Successes

More than a year after the completion of the grant, many of the GPS/GIS lab exercises, lecture modules and student assignments remained as a component of the modified upper and lower division courses. The technology has become an integrated component of these courses and an important aspect of the agriculture curriculum. Students will continue to be exposed to both the basic common core of GPS/GIS information as well as specific discipline-related applications of the technology.

One measure of meaningful learning is the ability of students to take knowledge gained in a course and apply that knowledge to new problems. The goal is for the student to understand the theory underlying the technology and to be proficient in its use, and for the student to develop an appreciation for how and when to apply the technological tool in new, unfamiliar situations. Students in the Landscape Design option of the B.S. in Horticulture curriculum often enroll in the course designated PS 435, Nursery Management, during the fall semester prior to enrolling in the required spring capstone course, PS 452, Landscape

Architecture. PS 435 was modified, as part of the grant project, to introduce students to the GIS 'MAPS Atlas'. This program divides the state of Montana into 18,000 rectangles (cells) each measuring about two miles by three miles and represents the land and climatic characteristics for each through a compilation of 150 environmental attributes. One lecture is devoted to a general explanation of GIS, an introduction to MAPS Atlas and a hands-on opportunity to explore the program. During the next lab, student teams work through an exercise requiring them to analyze attributes important for nursery production, such as minimum winter temperature, soil factors, proximity to population centers, etc. By the end of the exercise, students have begun developing maps detailing regions of the state possessing high, medium or low potential for nursery stock production based on the attribute maps contained in the program. Teams complete their maps out of class, usually within 2 weeks, with instructor input. The goal of the exercise is to provide the students with a framework to select attributes they deemed important for production and a tool to then compile those student-selected attributes into a site suitability map. Thus, the students gain experience using the program as a site analysis tool. Student teams in PS 452 are required to produce detailed landscape plans for sites located around the state. These plans also require a thorough site analysis including information on climate, soils and topography. We found that students who had enrolled in PS 435 the previous semester, returned and requested the use of MAPS Atlas GIS as a tool to assist them with the new PS 452 project. This example illustrates how GIS knowledge gained in the modified PS 435 course interfaced with a course outside the grant project. Students achieved a certain level of proficiency using the MAPS Atlas GIS in PS 435, perceived the program as a useful tool and employed it to solve a problem in a new environment encountered several months after PS 435 concluded.

Table 2. Exit Survey Responses of Participating Faculty

Survey Question	Participant Response SA	A	N	D	SD
1. GPS/GIS proficiency is important to students in the agriculture curriculum I serve.	5	2			
2. My initial interest in the project reflected my desire to expose students in my courses to GPS/GIS technology.	3	4			
3. My initial interest in the project reflected my own desire to become more proficient in GPS/GIS technology.	1	5			1
4. Currently, most students in the College of Agriculture at MSU are not adequately trained in GPS/GIS.	2	4	1		
5. The project resources (workshops, slide sets, web-based lab) adequately prepared me to incorporate GPS/GIS lectures, labs or modules into my course.		5	1		1
6. The project improved the awareness of GPS/GIS applications in agriculture among students in my class.	3	3	1		
7. The project improved the GPS/GIS technology proficiency of students in my class.			5	1	1
8. I feel I successfully implemented GPS/GIS lectures, labs or modules in my class.	2	4	1		
9. I did not use as much GPS/GIS material in my course as initially planned.		4		3	
10. I developed GPS/GIS information for use in my course, but did not implement it.				4	3
11. The GPS/GIS lecture, lab or module developed as a result of this project will remain as part of my course in the future.	2	2	1	1	1
12. The GPS/GIS lectures, lab or module developed as a result of this project will not remain as part of my course, but students will be encouraged to enroll in LRES 357.		2	2	3	
13. The development of LRES 357 reduces the need for me to include GPS/GIS information in my course(s).	4	2		1	
14. LRES 357 should be a required course within the option I teach.	4	2		1	
15. Identify a major obstacle to increased implementation of the project in your course.					
no room in current courses for new GPS/GIS info (4 responses)					
lack of GPS/GIS equipment (3 responses)					
not all students exposed to basic pre-requisite GPS/GIS material prior to advanced applications (1 response)					
some students receiving the same basic info in more than one course (1 response)					
16. What was the major benefit of this project to students in your course?					
increased awareness of GPS/GIS agriculture applications (5 responses)					
increased ability to operate GPS/GIS equipment (1 response)					
improved employability of students (1 response)					

n = 7
SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree.

Obstacles

Most participating faculty indicated that their interest in the project reflected their own desire to become more proficient in GPS/GIS technology (Table 2). This interest translated into a high level of enthusiasm for the project among faculty and substantially improved its implementation. We realize, however that this may not always be the case and stress the importance of faculty 'buy in' at an early stage. In other studies, faculty resistance to technological change was significant if the participants felt that they were required to adapt to technology (Hogle et al., 2000). In our opinion, affecting change over a broad curriculum requires a 'critical mass' of faculty committed to the use of the technology in the curriculum. Two other issues were identified as obstacles to increased implementation of the project in specific courses: lack of equipment and content competition. Professional grade GPS receivers and supporting hardware and software, although expensive, are necessary components of a project such as this. While faculty had access to 10 hand-held GPS units, this was often an insufficient number to allow students adequate time with the equipment. We recommend one GPS unit per two students as a minimum to allow for meaningful student-equipment interaction. The issue of limited equipment access may explain why faculty felt that the project improved student awareness of GPS/GIS applications in agriculture, but generally did not feel that the technological proficiency of the students improved (Table 2). Perhaps a more difficult issue impacting the implementation of such projects is that of content competition. Many upper and lower division college courses suffer from content overload. How can an instructor introduce additional GPS/GIS content to a course without eliminating or modifying existing content? Four of seven respondents to the exit survey indicated that they did not use as much GPS/GIS material in their courses as initially planned, while three indicated that the developed GPS/GIS modules might not remain as a part of their course in the future (Table 2).

New Directions

Discussions during the spring and summer of 1997 addressed the desire to have an entire course dedicated to the use of GPS technologies. The course, LRES 357, GPS Fundamentals and Applications in Mapping (http://www.montana.edu/places/gps/lres357), was developed during the summer of 1997 and taught for the first time in fall of 1998. The development of LRES 357 offered more detailed GPS training for agriculture students desiring a more complete treatment of the subject. Faculty, however, continued to incorporate basic GPS/GIS lectures into their courses. For this reason, the GPS slide set, divided into basic and advanced GPS topics, was posted on the Internet (http://www.montana.edu/places/gps) for easier faculty/student access. Additionally, homework questions to accompany the slide sets were distributed to participating faculty. In fall 2000, work began on a website outlining our experience with the USDA Higher Education Challenge Grant program and sharing resources with others who hope to integrate GPS/GIS technologies into their curriculum. The website may be found at http://www.montana.edu/places/usda_ed/index.html.

Summary

This project demonstrated that valuable exposure to GPS/GIS technology occurs by incorporating basic core information into existing lower division courses and discipline-specific GPS/GIS applications in upper division courses. This approach may serve as an alternative for students residing outside geography departments or not wishing to add a GPS/GIS minor, should one exist. There have been a number of recommendations for possible GPS/GIS curricula (Nyerges and Chrisman, 1989; Wright, 1992). Most proposed curricula do not adequately address the issue of prerequisites. Background courses in computer science, remote sensing, statistics, and cartography are all recommended. Most agree that GPS/GIS technology education is connected to a larger curriculum. We believe, however, that significant gains can be made in GPS/GIS education in already-crowded college of agriculture programs without the addition of numerous prerequisite courses. Montana State University College of Agriculture students were exposed to important aspects of the technology within their own programs of study, using examples and applications relevant to their discipline.

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