ABSTRACT

CARR, JOHN DAVID. Assessing Embedded Geospatial Student Learning Outcomes. (Under the direction of Dr. Heather M. Cheshire.)

Geospatial tools and technologies have become core competencies for natural resource professionals due to the monitoring, modeling, and mapping capabilities they provide. To prepare students with needed background, geospatial instructional activities were integrated across Forest Management; Natural Resources; Fisheries, Wildlife, & Conservation Biology; and Environmental Technology & Management curricula in the Department of Forestry and Environmental Resources at North Carolina State University. As additions were made to curriculum, the effectiveness of the integration and how well students were meeting geospatial outcomes were unknown.

The purpose of this study was to evaluate student attainment of geospatial outcomes. The study was conducted in three phases to address three study objectives. The first objective was to develop an outcomes-based framework to assess student learning. An assessment framework is a conceptual approach for identifying foundational elements underpinning assessment activities such as identifying the type of assessment, identifying stakeholders, articulating student learning outcomes, and identifying criteria for success. The second objective was to develop assessment methods, identifying where and how often evidence of learning would be collected and analyzed. The third objective was to report results of the assessments, commenting on the current state of student learning and suggesting possible avenues for improving student learning, geospatial integration, and the assessment process.

To develop our framework, we reviewed assessment literature and consulted assessment experts on campus. That guidance, in combination with our assessment goals, led us to choose a formative and utilization-focused assessment approach focused on intended uses by key stakeholders. Our stakeholders included facilitators responsible for developing

and integrating geospatial activities in courses, faculty with geospatial integration in their courses, and program directors of curricula with integration in courses. We worked with NC State University Planning and Analysis and developed structured interviews. Content analysis of interview data identified stakeholders' geospatial objectives, where they would look for evidence of learning, and their criteria for success. This information helped guide the development and implementation of assessment methods.

Faculty and administrators indicated that they believed evidence of student learning was demonstrated through students' deliverables or could be tested directly. In response, we collected students' maps, lab reports, term projects, and capstone course management plans and evaluated them with rubrics. Other assessment tools included tracking questions embedded on tests and quizzes, pre-post tests before and after series of instructional laboratories, and longitudinal surveys designed to solicit students' awareness of and confidence in their ability to use geospatial tools.

Students' deliverables produced mixed results, but students in programs with integration incorporated spatial analysis within their assignments successfully. Pre-post tests showed that students' knowledge increased after course-embedded activities, and surveys indicated students' awareness and confidence were significantly increased at the completion of their programs. Rubrics used to assess students' term projects and capstone management plans revealed that forestry seniors met skills-based, information literacy, and conceptual knowledge outcomes. Natural resources seniors independently chose to use appropriate spatial analysis in their term projects and management plans, demonstrating adoption and internalization of spatial problem solving techniques.

Curricula and courses we have worked with the longest have more instructional opportunities and the most seamless integration into ongoing coursework. The assessments showed that students in these programs performed better than students in programs with fewer learning opportunities. As a result, we are working with faculty in all curricula to design and facilitate activities that effectively complement students' classroom activities and that are more closely aligned with course content and performance expectations. This approach helps students utilize the knowledge and tools in authentic situations. The assessments helped us identify instructional missteps and unforeseen assessment issues that help us modify our teaching and assessment methods. The assessments are also producing baseline student learning information we can use to objectively evaluate both student performance and our performance as educators. We believe this study will be useful to institutions with similar goals and needs, and that the assessment methods can be adapted to fields of instruction other than forestry, natural resources, and spatial information systems.

Assessing Embedded Geospatial Student Learning Outcomes

by
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DEDICATION

I dedicate this dissertation to my sisters, Nancy, Carole, and Laura.

BIOGRAPHY

John David Carr was born in Durham, NC, and attended elementary through high school in Fayetteville, NC. While in high school, David worked with Moorman, Kizer & Reitzel, Inc., where he was first exposed to map making and land surveying. After high school, David pursued a bachelor's degree in Natural Resources at NC State University. During his junior year, David co-oped with Union Camp Corp., and spent the next six months working in the Roanoke region of North Carolina and Virginia. During this time, David was tasked with digitally mapping the company's holdings in the region using geospatial technologies. These experiences profoundly influenced David's future research and career interests.

After graduating from NC State, David started a career with the NC Forest Service. David enjoyed talking with landowners, loggers, and students, as well as his day-to-day resource management duties. While with the Forest Service, David had the opportunity to join a wildfire hand crew and fought the Trout Canyon, Whiskey, and Great West Basin incident fires in Nevada (2000). Driven by his past mapping experiences and growing interest in geospatial tools and technologies, David returned to NC State to pursue a Master's degree, concentrating in Spatial Information Systems.

After completing his Master's, David relocated to the DC area and started a new career with Earth Satellite Corporation. While with EarthSat, David had the opportunity to work with a variety of geospatial data from around the world. EarthSat promoted a culture of ongoing training and education, which lead David to wonder how geospatial sciences could be taught given the rapid pace of technological change. David returned to NC State to pursue research investigating geospatial instruction in the hopes of finding ways to better prepare students to apply spatial analysis to natural resource management issues.

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thank the students for their participation. I think you should know there is much you have taught me, and I thank you for those lessons.

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1.0 Introduction

Geospatial tools and technologies are important to environmental professionals because up-to-date spatial data are essential to the successful monitoring, modeling, and mapping of our landscapes. Analysis of ecological data can help us understand, avoid, and mitigate the effects of natural and manmade disturbance. Geospatial technologies provide platforms for collecting and analyzing ecological data, identifying spatial relationships, and communicating information with maps. As a result, natural resource professionals were early adopters of geospatial technologies (Weir 1989) as an integral component of resource planning, management, and assessment (Hess and Cheshire 2002; Merry et al. 2007).

Students in postsecondary degree programs in the Department of Forestry and Environmental Resources at North Carolina State University (NC State) are exposed to a broad range of geospatial principles, tools, and technologies. This exposure is primarily achieved by embedding geospatial material across curricula and courses within the department. The overall objective for embedding the material is for students to become accustomed to the technologies, see them as tools for effective and efficient planning, decision-making and problem solving, and adopt their use as part of being environmental professionals. Theory and application of geospatial analyses appear throughout students' regular coursework in the form of lectures, laboratories, and projects. To understand the effectiveness of this embedded approach, we developed an assessment program to evaluate students' awareness of and ability to use geospatial technologies to address resource management issues.

1.1 Background

1.1.1 Geospatial Information Science and Technology

Geospatial tools and technologies include geographic information systems (GIS), global positioning systems (GPS), remote sensing, cartography, spatial statistics, database management, and web services. The power of geospatial analysis stems from the association of location information with descriptive attributes that characterize the state of features at the time of data collection. Geospatial technologies provide the ability "to visualise and analyse spatial information in new ways, revealing previously hidden relationships, patterns and trends" (Wiegand 2001, p. 68).

During the past three decades, advancements in computer science and technology have changed the nature of spatial analyses. Increasing computing power, the advent of high-speed internet, and increasing availability of spatial data and software have made it possible to answer geographic questions more efficiently and cost effectively (Marble et al. 2003; DiBiase et al. 2006). As geospatial tools and technologies have become more prevalent and easier to use, the range of topics in which spatial analyses are applied has grown and the analyses themselves have become more sophisticated (DiBiase et al. 2006). These advances have changed the decision-making process in public, private, and research communities by "bringing digital spatial data sets and geographic analysis to the desktop computer" (Kerski 2001, p. 72).

1.1.2 Geospatial Model Curricula Development

Duane Marble is recognized as one of the most influential advocates for a geospatial model curriculum (DiBiase et al. 2006). In his 1979 paper, *Integrating Cartographic and Geographic Information Systems Education*, Marble predicted that the increasing prevalence of computer technologies and their decreasing costs would have a transformative effect on geography, cartography, and digital data (Marble 1979). This is one of the first publications to which the origins of geospatial curricular development can be traced.

Even 30 years ago, Marble (1981) stated that the increasing pace of technological change had outstripped the ability of universities to adapt their geospatial science programs and adequately train graduates. He suggested that failure by universities to take action would result in a growing gap between what university faculty members were teaching and the needs of the user community (Marble 1981). In later works, Marble suggested that increasing demand on institutions to provide GIS training resulted in introductory courses that emphasized software manipulation rather than the foundational principles upon which the technologies are based (e.g., Marble 1998). However, the University Consortium for Geographic Information Science *GIS&T Body of Knowledge* (DiBiase et al. 2006, p. 27) states:

> Critiques of the preparedness of graduates should not be taken to imply that GIS&T educators have neglected their responsibilities. In fact, "GIS instructors in higher education have shown an almost exemplary concern for teaching" (Unwin, 1997, p. 2). Since the late 1970s, GIS, cartography, and remote sensing educators have proposed frameworks to guide curriculum planning … and demonstrated the propriety of including GIScience within general education curricula (DiBiase, 1996).

There have been several efforts to develop model geospatial curricula (Table 1.1). The National Center for Geographic Information and Analysis (NCGIA) developed a *Core Curriculum in GIS* between 1988 and 1990. More than 1,500 institutions requested copies of the curriculum and over 100 agreed to implement the curriculum and share results of the implementation (DiBiase et al. 2006). In 1995, the NCGIA began development of the *Core Curriculum in GIScience*. This updated and expanded curriculum included the study of the theory and practice of spatial analysis (i.e., GIScience) and was last updated on August 13, 2000.

Development of the *Remote Sensing Core Curriculum* was initiated by the NCGIA in 1992 and is currently maintained by the American Society for Photogrammetry and Remote Sensing (ASPRS). Instructional materials are freely available online. There are no measures in place to track their use; however, server logs store the Internet Protocol address of computers that access materials and approximately two hundred unique visitors access the site each day (Joseph Knight, personal communication, August 27, 2011).

The University of Mississippi Institute for Advanced Education in Geospatial Sciences (IAEGS) began developing the *IAEGS Model Curriculum* in 2001. The curriculum is currently maintained by the University of Mississippi and ASPRS. Courses are available to colleges and universities, government agencies, and industry for a fee and content is delivered via an online course management system. The IAEGS curriculum is undergoing major course revisions and transitioning to a certificate based program. Current enrollment is low due to the transition; however, typical enrollment is approximately 100 students from four to five institutions each semester (Christopher Reichley, personal communication, August 29, 2011).

The first geospatial model curricula efforts began after the 1997 meeting of the University Consortium for Geographic Information Science (UCGIS). At the assembly, eight challenges to geospatial education were identified (DiBiase et al. 2006; DiBiase 2007). In 1998, the USGIS established a Model Curricula Task Force that included representatives from academia, industry, and government. Their goal was to comprehensively inventory the geospatial domain and propose a model curriculum. These efforts culminated in the release of what has come to be known as *The Strawman Report* (Marble et al. 2003).

The UCGIS Model Curricula Task Force continued to review and update *The Strawman Report* after its initial release in 2003. A revised report was made available for public comment between November 2005 and January 2006 (DiBiase et al. 2006). A variety of stakeholder groups including higher education, industry, and government offered feedback during this public review period. In the summer of 2006, the updated report was published as the first edition of the UCGIS *GIS&T Body of Knowledge*. The *Body of Knowledge* consists of 10 knowledge areas, 73 units, and 329 topics. Intended uses include curriculum planning, program accreditation, program evaluation, and program assessment (DiBiase et al. 2006). The *Body of Knowledge* identifies foundational knowledge and skills all students should possess upon completion of an undergraduate geospatial program (DiBiase et al. 2006). This fundamental knowledge base is referred to as the common core and consists of 26 units in 9 knowledge areas (Table 1.2).

The *Body of Knowledge* is important because it can be used to "correct the observed mismatch between the educational process and industry needs" (DeMers 2009, p. S71), and because it helped to inspire our geospatial assessment efforts. Adoption levels for the *Body of Knowledge* are unknown; however, a Google Scholar article search for "UCGIS Body of Knowledge" in August 2011 resulted in 390 pages of search results, which included journal articles, manuscripts, and citations. One indication of adoption is the GIS Certification Institute "considering modification of the GISP [Professional] certification program to include these [*Body of Knowledge*] core knowledge units in the certification process" (Butler 2007, p. 1).

1.1.3 Why Integrate Geospatial Technologies in Curricula and Courses?

Geospatial technologies play an important role in providing environmental professionals with tools and information they can use to help plan for, identify, and solve problems. Early in their development, rapid growth in the use of geospatial technologies resulted in a deficit of skilled geospatial practitioners (Raper and Green 1992) and the pace of technological change outpaced the ability of higher education systems to accommodate those changes (Marble 1998). Labor statistics show that the demand for skilled geospatial practitioners remains high, and an increase in demand is predicted for the future (US Department of Labor 2005; Wing and Sessions 2007). Therefore, higher education systems must evaluate what geospatial material they are teaching, how they are teaching it, and how the material being taught fits with curricular learning outcomes on an ongoing basis.

Studies have been conducted to explore the demand for geospatial skills in forestry and natural resources professions. Kammesheidt et al. (2007) conducted a survey of 77 forestry related companies, agencies, and non-governmental organizations in Malaysia and found that geospatial technical knowledge is highly expected by employers in the management and procurement sectors of the industry. Merry et al. (2007) surveyed 108 recent forestry and natural resources graduates from the University of Georgia and found that 43% of the 62 respondents used geospatial technologies at least every other day. A study of state agencies by the North Carolina Office of State Budget and Management (OSMB) shows “that at least 1,200 employees use GIS data daily for decision-making to support their operations” (OSBM 2008, p. 14). The number of users in North Carolina increases substantially when users from local government, private, and research communities are included (OSBM 2008).

Colleges and universities are the leading source of geospatial degree and certificate programs in the United States (Wing and Sessions 2007). One of the greatest difficulties facing geospatial technologies in higher education is developing and assessing curricula that can accommodate the diverse geospatial user community (Kemp and Wright 1997). Forestry and natural resources higher education programs are particularly attuned to the needs of public, private, and research enterprises they serve (Kammesheidt et al. 2007); therefore, they include geospatial sciences within their curricula. In response to the need for resource professionals to possess geospatial skills, the Society of American Foresters requires accredited forestry degree programs to include spatial analysis within their forest management curriculum (SAF 2004).

In their investigation of geospatial technology integration within the forestry and natural resources undergraduate curricula at NC State, Hess and Cheshire (2002, p. 29) found that “students returning from job interviews and from work cooperatives report that potential employers in the field of natural resources are looking for employees with some experience using spatial analysis tools.” Fisher and Toepfer (1998) surveyed 42 universities with fisheries programs and found that of the 24 responding institutions, 96% of fisheries students were taking geospatial related courses. Dodds and Meitner (2004) suggested that questions surrounding geospatial integration into forestry and natural resources degree programs have changed from whether or not the tools and technologies should be included to whether or not universities are meeting current and future students’ needs.

As the demand for skilled geospatial practitioners increases and the number of fields requiring geospatial knowledge and abilities expands, it is vital that graduates are equipped with a geospatial background that prepares them to apply the tools effectively and adapt as the technologies change (Marble 1981; Marble et al. 2003). To meet this need, faculty in the Department of Forestry and Environmental Resources at NC State have developed and embedded geospatial activities across undergraduate curricula and courses within the department. The need for geospatial integration and the need for approaches to achieve it have been accepted by the faculty. However, how well students are achieving geospatial learning outcomes and the impact of geospatial curriculum integration are unknown.

1.2 Study Goals and Objectives

The purpose of this study was to develop a framework and methodologies needed to assess student attainment of geospatial learning outcomes. Outcomes assessment provides insights regarding how well students are learning and, in turn, how to improve student learning. Assessment leads to program enhancement by revealing instructional weaknesses and creating instructor development and research opportunities. Reporting assessment findings contributes to the geospatial education knowledge base; at the time of the compilation of the literature review included here, we found no published reports of geospatial outcomes assessment.

The overall goals for geospatial integration are to expose students to geospatial tools and technologies and impart an awareness of the spatial context in which humans, the environment, and ecological functions and services interact. Many faculty with integration in their courses would like integration to equip undergraduates with geospatial knowledge, skills, abilities, values, and attitudes natural resource professionals should possess. Facilitators responsible for developing course-embedded geospatial activities also have expectations of what can be achieved through integration (Table 1.3). We established assessment methods and measures needed to identify geospatial learning outcomes and determine how well they are being met.

Specific study objectives were to:

(1) develop a flexible geospatial assessment framework (Chapter 2);
(2) plan, develop, and test assessment methods (Chapter 3); and
(3) report results of the assessments and comment on the current state of student learning (Chapter 4).

Specific research questions addressed in this study were:

- What are Department of Forestry and Environmental Resources stakeholders' intended geospatial student learning outcomes?
- What is the desired learning level for each outcome?
- Where can evidence of the desired learning behavior be observed or measured?
- What assessment methods are appropriate for capturing and analyzing evidence of learning?

- How well are geospatial student learning outcomes being achieved?
- How can student learning be improved?
- How can geospatial integration be improved?
- How can the assessments be improved?

This thesis is composed of three manuscripts, one corresponding to each of the three specific study objectives. Each manuscript addresses a specific stage in the assessment process. When taken together, these materials provide an example of how to frame an assessment and make it operational. Assessment results were used to comment on how student learning, geospatial integration, and the assessments could be improved. Many colleges and universities have integrated geospatial sciences within their programs. This study could be useful to institutions with similar goals and needs, and the assessment methods can be adapted to disciplines other than forestry, natural resources, and spatial information systems.

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Wing, M. G., and J. Sessions. 2007. Geospatial Technology Education. *Journal of Forestry* 105 (4):173-178.

Table 1.1. Geospatial model curricula development efforts.

Model curricula	**Year initiated**	**Source**
National Center for Geographic Information and Analysis, *Core Curriculum in GIS*	1988	Goodchild, M. F., and K. Kemp (Eds.). 1990. *NCGIA Core Curriculum in GIS*. National Center for Geographic Information and Analysis, University of California, Santa Barbara, CA. http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/toc.html (accessed March 23, 2008).
International Center for Remote Sensing Education, *Remote Sensing Core Curriculum*	1992	International Center for Remote Sensing Education. 2011. *Remote Sensing Core Curriculum*. http://www.r-s-c-c.org/index.html (accessed February 18, 2008).
National Center for Geographic Information and Analysis, *Core Curriculum in GIScience*	1995	National Center for Geographic Information and Analysis. 2000. *The NCGIA Core Curriculum in GIScience*. http://www.ncgia.ucsb.edu/giscc/ (accessed November 7, 2007).
University Consortium for Geographic Information Science, *The Strawman Report*	1998	Marble, D. F., and the Model Curricula Task Force. 2003. *Development of Model Undergraduate Curricula for Geographic Information Science &Technology*: *The Strawman Report*. Alexandria, VA: University Consortium for Geographic Information Science. http://www.ucgis.org/priorities/education/priorities/final%20strawman%20text.pdf (accessed January 10, 2008).
Institute for Advanced Education in Geospatial Sciences, *IAEGS Model Curricula*	2001	Institute for Advanced Education in Geospatial Sciences. n.d. *IAEGS Model Curricula*. University of Mississippi. http://geoworkforce.olemiss.edu/ (accessed March 12, 2008).
University Consortium for Geographic Information Science, *GIS&T Body of Knowledge*	2005	DiBiase, D., M. N. DeMers, A. Johnson, K. Kemp, A. T. Luck, B. Plewe, and E. Wentz (Eds.). 2006. *Geographic Information Science and Technology Body of Knowledge*. Washington, DC: Association of American Geographers.

Table 1.2. UCGIS *Body of Knowledge* core units and associated knowledge areas. (Source: DiBiase et al. 2006)

Knowledge area	**Units**	**Knowledge area**	**Units**
Analytical Methods (AM)	AM3: Geometric measures AM4: Basic analytical operations AM5: Basic analytical methods	Design Aspects (DA)	DA4: Database design
Conceptual Foundations (CF)	CF3: Domains of geographic information CF4: Elements of geographic information	Data Modeling (DM)	DM2: Database management systems DM3: Tessellation data models DM4: Vector and object data models
Cartography and Visualization (CV)	CV2: Data considerations CV3: Principles of map design CV6: Map use and evaluation	Data Manipulation (DN)	DN1: Representation transformation DN2: Generalization and aggregation
Geospatial Data (GD)	GD1: Earth geometry GD3: Georeferencing systems GD4: Datums GD5: Map projections GD6: Data quality GD7: Land surveying and GPS GD10: Aerial imaging and photogrammetry GD11: Satellite and shipboard remote sensing GD12: Metadata, standards, and infrastructures	GIS&T and Society (GS) Organizational and Institutional Aspects (OI)	GS6: Ethical aspects of geospatial information and technology OI5: Institutional and inter-institutional aspects OI6: Coordinating organizations (national and international)

Table 1.3. Facilitators' expectations of what can be achieved through geospatial integration.

Through integration in curricula and courses, students should be able to:
• Describe GIS, GPS, and digital imagery technologies
• Locate, download, and manage a variety of spatial data types
• Plan and execute a GPS field data collection mission
• Perform routine spatial analysis functions (selections, calculations, geoprocessing)
• Apply the tools to natural resources problems (make meaning of the functions)
• Make and communicate with maps effectively

2.0 A Framework to Assess Geospatial Learning Outcomes

2.1 Abstract

Geospatial tools and technologies have become core competencies for natural resource professionals. To equip undergraduates with needed background, geospatial instructional activities were recently integrated across curricula and courses in the Department of Forestry and Environmental Resources at North Carolina State University. The effectiveness of the integration and how well students were meeting geospatial objectives are unknown. In this manuscript, we describe the development of a framework to assess geospatial learning outcomes. Structured interviews were conducted to solicit outcomes from faculty and program administrators in the department. Content analysis of interview data revealed faculty's intended geospatial learning outcomes, where they believed evidence of learning could be observed or measured, and their standards for success. The assessment framework described here provided a foundation for planning and implementing assessments and communicating findings. Assessment methods included using taxonomies of educational objectives to assess students' term projects and capstone management plans. Analyses showed forestry seniors met skills-based, information literacy, and conceptual knowledge outcomes. Natural resources seniors chose to use spatial analysis in their projects and management plans, demonstrating adoption and internalization of geospatial approaches. Other assessments using tracking questions, rubrics, pre-post tests, and surveys are ongoing to further characterize student achievement of geospatial outcomes.

2.2 Introduction

Geospatial tools and technologies provide spatial data and analysis capabilities that enhance the ability to study, monitor, and manage natural resources. As a result, natural resource professionals were early adopters of geospatial technologies (Weir 1989). The technologies have made collecting and maintaining geographically referenced datasets easier, allowing problem-solving, planning, and decision-making tasks to be performed more efficiently. Today, geospatial tools and technologies are core competencies for natural resource professionals (Hess and Cheshire 2002; Wing and Bettinger 2003; Merry et al. 2007; Wing and Sessions 2007).

Duane Marble (1979) predicted that advancements in computer technologies and their decreasing costs would have transformative effects on geography, cartography, and digital data. Increasing computing power and the availability of spatial data and software have made it possible to answer geographic questions more efficiently and cost effectively (Marble et al. 2003; DiBiase et al. 2006). As geospatial tools and technologies have become more prevalent and easier to use, the range of disciplines in which spatial analyses are applied has grown (DiBiase et al. 2006).

Studies show demand for skilled geospatial practitioners is high and will likely continue to increase (Table 2.1), and higher education systems have become the primary provider of geospatial education and training (Wing and Sessions 2007). Efforts have been undertaken to integrate geospatial sciences within curricula and courses and study their use in an academic setting (Table 2.2). Forestry and natural resources programs have articulated specific geospatial learning objectives (Hess and Cheshire 2002), and faculty have integrated the tools into courses demonstrating their application across a variety of disciplines (e.g., Lee et al. 1999; Stout and Lee 2004; Linehan 2006; Simmons et al. 2008). However, the effectiveness of geospatial integration and how well students are meeting geospatial objectives is, as of yet, unknown.

Outcomes-based assessment is increasingly important in higher education. Ewell (1991, p. 75) stated that “assessment has become, for many institutions, a condition of doing business.” Stakeholders are demanding greater accountability and that student learning be documented (e.g., Cook et al. 2006; Prager and Plewe 2009). In response, we developed an assessment program to document student achievement of geospatial learning outcomes in the

Department of Forestry and Environmental Resources at North Carolina State University (NC State).

2.3 Geospatial Integration

Geospatial integration has long been part of the forestry and natural resources programs at NC State. Hess and Cheshire (2002) described specific integration objectives for the Department of Forestry and Environmental Resources, including (1) exposing students to geospatial technologies in each year of their program, (2) providing technical support for the development and implementation of geospatial activities in undergraduate courses, and (3) evaluating the effectiveness of the approach. The overall goal was to demonstrate the application of geospatial technologies to resources management issues. Upon graduation, students should possess the skills necessary to interpret imagery, perform spatial analysis, and generate maps for reports and presentations.

Hess and Cheshire (2002) asserted that students need frequent exposure with repeated hands-on use in a disciplinary context to retain what they learn. This assertion has been supported in more recent literature on the value of targeted, repeated practice (Ambrose et al. 2010). To accomplish the desired exposure, spatial analysis activities were embedded across multiple courses in the department, exposing students to geospatial tools in multiple years of their programs (Table 2.3).

Integration efforts initially focused on the Forest Management and Natural Resources curricula. As demand for geospatial skills increased, integration expanded to include the Fisheries, Wildlife, & Conservation Biology and Environmental Technology & Management curricula. An introductory geographic information systems (GIS) course is required for some degree options and is a popular elective; however, many students' primary exposure occurs through course-embedded activities. These learning opportunities are designed to complement students' ongoing coursework and demonstrate application of the tools in a real-world context.

Colleges and universities are providing geospatial learning opportunities that meet their stakeholders' needs, and specific learning outcomes are being articulated. Wing and Sessions (2007) evaluated ten leading forestry programs in North America and found that all ten offered GIS courses; eight programs required undergraduates to complete a GIS course. Despite programs articulating and integrating geospatial outcomes, we found no published reports of how well students are meeting those outcomes. The purpose of this study was to develop an assessment framework that would allow us to evaluate students' geospatial learning and report how well those outcomes were being met and provide a starting template for other programs who might wish to develop measures for similar outcomes.

2.4 Developing an Assessment Framework

An assessment framework is a conceptual model that identifies foundational elements underpinning assessment activities. Common assessment framing tasks include (1) defining the purpose of the assessment, (2) reaching a consensus regarding assessment terminology, (3) identifying stakeholders, (4) articulating intended learning outcomes, (5) identifying possible methods and data sources, and (6) planning for the use and dissemination of findings. These steps result in building blocks that guide the development and implementation of assessment processes (i.e., an assessment framework). Once desired learning behaviors and methods for observing or measuring outcomes have been identified, assessment data are collected and evaluated.

2.4.1 Defining the Purpose of the Assessment

Patton (1997) described a utilization-focused evaluation approach in which assessments are focused on intended uses by key decision makers. Tyler's (1950) objectives-oriented evaluation approach outlines steps for determining how well objectives were met by comparing performance data with behaviorally stated outcomes (Table 2.4). Our goals were to assess faculty's intended geospatial outcomes so we, the geospatial integration facilitators, could use findings to improve student learning. Therefore, we combined elements of the utilization-focused and objectives-oriented approaches to frame our assessment program.

Two common types of assessment are summative and formative. Summative assessments produce information that can be used to judge the merit or worth of a program (Worthen et al. 1997; Palomba and Banta 1999) or calculate grades after learning should have taken place (Anderson and Krathwohl 2001). In a teaching and learning context, the purpose of formative assessments is to reflexively shape the program being assessed to improve student learning (Anderson and Krathwohl 2001). Our goal was to improve learning by more formally understanding and documenting student performance; therefore, we chose a formative approach.

2.4.2 Domains of Educational Objectives

Goals and objectives are the building blocks of courses, programs, and assessments. "Starting with teaching goals allows faculty to take a serious look at what they believe is most important to teach, and what they really want students to learn" (Angelo and Cross 1993, p. 36). Goals are broad statements whose scope encompasses the entire course or program (Landau 2001). Objectives describe changes in how students think, act, or feel if the desired learning occurred (Bloom et al. 1956; Anderson and Krathwohl 2001).

Learning objectives are commonly understood according to Bloom's taxonomy. Bloom et al. (1956) identified three domains of educational objectives: (1) the cognitive domain, (2) the affective domain, and (3) the psychomotor domain. The cognitive domain consists of six learning objective levels ranging from the simple recall of facts to the evaluation or creation of concepts and ideas. Most curriculum development has focused on the cognitive domain; as a result, most behaviorally stated objectives reflect cognitive outcomes (Bloom et al. 1956).

Krathwohl et al. (1964) described the affective domain, which is focused on learning behaviors related to attitudes and beliefs. The affective domain consists of five learning objective levels ranging from awareness to adoption and internalization. It can be difficult to communicate and assess affective outcomes because they rely on feelings, beliefs, values, and perspectives (Bloom et al. 1956; Krathwohl et al. 1964; Palomba and Banta 1999). In reviewing the history of affective objectives in general college education, Krathwohl et al. (1964) found that affective objective statements were largely unobservable and have disappeared from course descriptions, syllabi, and assessments over time.

Singer (1972, p. 7) described the psychomotor domain as encompassing “a broad spectrum of movement behaviors.” The psychomotor domain consists of seven learning objective levels ranging from perception to origination. “Many vocational, technical, and professional education programs require students to develop psychomotor skills that involve perception, dexterity, and coordination” (Palomba and Banta 1999, p. 29). Learning objectives in the psychomotor domain are classified by the complexity of motion and the sequence of acts necessary to complete the motion (Simpson 1972). The psychomotor domain is probably the least studied among the domains of educational objectives.

An understanding of the domains of educational objectives is helpful when articulating intended student learning outcomes. Learning outcomes should be stated using action verbs that characterize the types of behaviors students should exhibit if the desired learning has occurred (Palomba and Banta 1999; Anderson and Krathwohl 2001). Lists of key action verbs for stating outcomes at various learning levels in each domain have been developed (e.g., Selim et al. 2006). For example, terms that can be used to describe desired learning behaviors at the application level of the cognitive domain include the following: “calculate,” “contrast,” “diagram,” “execute,” and “implement.” Terms like “know,” “learn,” “appreciate,” and “understand” are not easily observed or measured and should not be used to state outcomes (Felder and Brent 2003).

2.4.3 Stakeholders and their Objectives

Potential stakeholders in higher education assessments include students, their parents, employers, faculty, and program administrators. For this study, we limited our stakeholder group to department faculty and administrators because we were primarily interested in assessing their intended geospatial learning outcomes. To document objectives and outcomes, we reviewed syllabi and laboratory handouts from courses with embedded geospatial activities. Outcomes identified in these materials included statements such as “the ability to make and communicate with maps” and “the ability to perform spatial analysis.” We also reviewed curricular outcomes documentation for programs in the department. There were no explicitly stated geospatial outcomes at the program level; however, geospatial outcomes were implied in statements such as “using appropriate methods and technologies,” “the ability to design sampling plans,” and “communication appropriate to the field.”

Faculty and administrators frequently commented that geospatial outcomes were important but not explicitly articulated. In response, we worked with NC State University Planning and Analysis to develop structured interviews to uncover (1) stakeholders’ geospatial objectives, (2) where to look for evidence of student learning, and (3) the same stakeholders’ criteria for success. The results of this process were two sets of structured interview prompts, one for faculty (Appendix A) and one for program administrators (Appendix B). The interviews differed slightly to accommodate the need for broader outcomes statements at the curriculum level.

2.4.4 Structured Interviews and Learning Outcomes

Four program administrators and ten faculty members participated in the structured interviews. Three (of four) program administrators also taught courses with embedded geospatial activities and participated in both interviews. Interviews typically lasted ninety minutes and were digitally recorded; interview notes were also taken by the interviewer (JDC). The NC State Institutional Review Board for the Protection of Human Subjects in Research reviewed and approved interview methods and measures in place to protect participants' privacy and organizational intellectual property.

JDC performed content analysis of audio recordings and notes taken during the interviews using grounded theory (Glaser and Strauss 1967) and categorical coding (Miles and Huberman 1994) methods. Interview notes were reviewed and a list of possible response categories for each question was generated. Response codes that described specific learning behaviors within each category were then developed. We used key action words that participants used to describe the desired learning as code modifiers. This allowed an intended learning level to be assigned to each code.

Next, each interview recording was reviewed and each occurrence of a code was tallied. Each interview recording was reviewed twice. During the listening phase, deliberate efforts were made to reflect on what participants were trying to communicate. Categories and codes were added, removed, changed, grouped, and ungrouped as oversights, clarifications, and connections emerged. After the listening process was completed, categories and codes were again reflected upon, generalized, and desired performance levels were assigned using the domains of educational objectives (Bloom et al. 1956; Krathwohl et al. 1964), and Anderson and Krathwohl's (2001) taxonomy (Table 2.5).

The content analysis revealed five objective categories, and several recurring student learning outcomes that were expected by faculty and administrators (Table 2.6). Skills-based objectives such as the ability to create sample plots, navigate to sample locations, and perform geoprocessing were mentioned approximately 98 times. There were high- and low-order objectives in the skills category; however, faculty generally desired that skills-based objectives be met at the application level. Information literacy objectives were mentioned approximately 16 times and centered on students understanding how to find appropriate geospatial data and employ basic file naming and management practices. Conceptual knowledge objectives were mentioned approximately 29 times and focused on students understanding how geospatial approaches were complementary to resource management tasks. Metacognitive knowledge objectives were mentioned approximately 12 times and primarily dealt with students understanding how they learn, what they do not know, and strategies for seeking help. Faculty expressed affective objectives approximately 27 times, and the key action verbs used to describe the desired outcomes indicated students should "value," "adopt," and "internalize" the use of the tools.

Faculty's viewpoints on the purpose of integration generally fell into two categories. Some believed integration should expose students to the technologies, making them aware of the types of functions and analyses those technologies can bring to bear on resource management issues. These faculty believed that the pace of technological change, especially in geospatial sciences, will result in skill sets that are quickly outdated; therefore, what should be learned is the process of discovery, not the mechanics of a software interface or device. Other faculty believed program graduates should possess application level analysis skills and abilities. These faculty viewed spatial analysis as a routine part of daily resource management tasks that students should be able to perform upon graduation. Our goal was to develop instructional opportunities and assessments that addressed both viewpoints.

Faculty and administrators were also asked where they would look for evidence of student learning and to describe their criteria for success. In general, participants agreed that students' ability to communicate clearly and knowledgeably orally, in writing, and using maps were indicators of geospatial learning. Criteria for success included (1) the appropriate use of spatial analysis in planning and conducting projects, (2) communicating spatial methods and findings effectively in reports, (3) increasing use of the tools without prompting, and (4) active participation in classroom discussions using proper terminology. Most faculty stated that the geospatial competencies they desired were essential and the appropriate performance standard should be 100% success for individual students. Acknowledging that this standard was not attainable, most participants suggested counts (e.g., 16 students of 20) or percentages should be used for group or aggregate data. In response to this feedback, we set our initial performance target at 80% as satisfactory.

2.5 Assessing Students' Deliverables

Faculty and administrators indicated that they believed evidence of student learning was demonstrated through students' coursework. Students' deliverables were collected and evaluated to generate assessment data needed to determine how well learning outcomes were being met. The data consisted of maps, lab reports, term projects, and capstone course management plans (Table 2.7). Students' maps and lab reports were collected at the conclusion of geospatial activities embedded in courses. Students often provided two copies of maps and lab reports, one for instructors and one to be archived for assessment. Term projects came from courses with projects that contained a geospatial component; faculty supplied copies of reports they had available. Management plans are from capstone courses and represent semester-long group and individual efforts. Available data consisted of 164 maps, 24 lab reports, 11 term projects, and 10 capstone management plans.

We used Anderson and Krathwohl's (2001) taxonomy to evaluate each artifact of learning. The taxonomy allows users to identify knowledge types and cognitive processes expressed in each deliverable. The knowledge type and cognitive process, as identified using the taxonomy table, was compared to the faculty's desired learning level to determine if outcomes were achieved successfully. A tally of successes and failures was kept for each deliverable, course and year to document the number of outcomes satisfactorily met.

Students' maps alone were not a useful source of assessment data. Although many maps were visually appealing, without accompanying reports discussing the meaning of the underlying analysis, maps simply indicated that students had participated in a geospatial activity, including the management of data. Lab reports that included maps provided richer assessment opportunities. Twenty-four lab reports (representing 55 students over three semesters) from a senior forest management course were evaluated. In their reports, students were required to demonstrate the ability to (1) describe the relationship between their field measurements and the results of a spatial interpolation, (2) support findings using ancillary spatial data, and (3) compose polished maps contrasting two interpolation methods. Assessment criteria were for students to apply appropriate analysis procedures and explain how those procedures were conceptually linked to their field measurements. Fifty-nine percent of students successfully achieved the intended learning outcomes for this activity.

Term projects and capstone management plans from four courses were evaluated (Table 2.8). Five capstone management plans from a senior forest inventory and planning course were evaluated. The plans frequently referenced maps of derived data with little discussion of the hardware, software, or spatial analysis methods used to create them – the mechanics underlying analysis are not appropriate for inclusion in these management plans. Common analysis tasks included identifying cover types, stand boundaries, riparian buffers, wildlife plots, and area calculations. The quality of the work was quite high, and indicated that students were operating at the application and analysis levels of the cognitive process dimension. The forestry capstone plans satisfied the 80% performance standard for the skills-based and conceptual knowledge outcomes; however, these documents did not produce assessment data for metacognitive or affective outcomes.

Maps and derived spatial data were less common in the five natural resource management capstone plans. Common maps included general reference, soils, topography, and land cover. There was little discussion of spatial analysis in the reports because the project focused on economic impacts of environmental tradeoffs. Spatial analysis was used to identify suitable firebreak locations, locate potential wetland mitigation sites, and perform area calculations so net present value of management alternatives could be calculated. The depth and number of analyses varied among the reports and indicated that students were operating at the lower application levels of the cognitive process dimension (i.e., the routine application of analysis procedures to familiar tasks). The natural resources capstone plans did not satisfy outcomes according to the performance standard. The tools were integrated into the reports appropriately; however, the frequency and complexity of geospatial approaches that the reports demonstrated failed to meet the intended performance standard. The natural resources plans did indicate some level of affective outcomes attainment (e.g., adoption and internalization) because inclusion of any spatial analysis beyond a required reference map was completely self-directed.

Seven term projects from a senior environmental impacts course were evaluated. The spatial data analyzed in the reports included natural heritage sites, open space, and demographics. Discussion and complexity of analysis varied among the reports. One group performed feature extraction, another employed a sampling scheme, and others presented polished maps. As with the natural resources capstone course, students were operating at the application level of the knowledge dimension, and students' choice to incorporate spatial analysis into their reports was a demonstration of some affective outcomes attainment.

Four term projects from a junior natural resource measurements course were evaluated. The subject of maps and analyses included general reference, historical aerial photography, land cover, topography, soils, wetlands, vernal pools, and field sample planning. Maps were used creatively to communicate field data by attribute and location, such as coarse woody debris volume. Maps were also used to show discrepancies between published maps and students' field observations. The level of detail varied among reports; however, thorough descriptions of hardware, software, and analysis techniques were provided – the mechanics underlying analysis are appropriate for inclusion in these reports. Students successfully integrated and communicated spatial information in the reports and were operating at the routine application levels of the knowledge dimension. The reports suggest students were making progress toward achieving skills-based and conceptual knowledge outcomes.

2.5.1 Other Assessment Methods

Assessment works best when multiple methods and measures are used (Worthen et al. 1997), and in this study structured interview participants identified a number of different expected outcomes and possible data sources. As a result, we developed a variety of instruments, including recurring tracking questions, evaluative rubrics, pre-post tests, and knowledge surveys. These instruments are used in a variety of courses and are beginning to produce useful outcomes data. Carr et al. (2011) provide an overview of assessment methods and their implementation.

Recurring tracking questions in a freshmen course show a slight decline in students' recognition of terminology, and a slight increase in conceptual knowledge from 2011 to 2012. Tracking questions in a senior course show a 16% improvement from 2010 to 2011 in students' understanding of how geospatial technologies can be used to design and conduct an environmental study.

We used an analytic rubric to evaluate deliverables from a geospatial immersion laboratory in a sophomore course. The analysis shows that 33 of 47 submissions (70%) were satisfactory and we identified possible barriers to success. Unsatisfactory submissions were cases where students either failed to follow directions, or we failed to clearly communicate our expectations to students who had not previously encountered the technologies. A rubric was also used to evaluate laboratory reports from a senior course with fairly robust geospatial integration. Each year, greater emphasis is placed on reflection prior to students writing their lab reports. We believe students' work and geospatial understandings have improved as a result, and the average rubric scores have increased by 11% from 2008 to 2010.

Pre-post tests were used to determine if students' knowledge and skills changed after course-embedded activities, and longitudinal knowledge surveys were used to determine if students' awareness of and confidence in their ability to use the tools changed over the course of their programs (Worthen et al. 1997; Palomba and Banta 1999). Pre-post tests show that, in almost every case, student knowledge increased after course-embedded activities. Many improvements were not statistically significant or failed to meet the intended performance target; however, assessments show the instruction is having a positive effect. The results of longitudinal knowledge surveys show that students' awareness and confidence were significantly increased at the completion of their programs and nearly met the 80% performance target – graduating students' awareness and confidence scores were approximately 78% satisfactory. Chapter 4 presents a detailed evaluation of student learning using pre-post test and knowledge survey data.

2.6 Discussion

Geospatial learning opportunities have been incorporated across curricula and courses in the Department of Forestry and Environmental Resources, and students are currently exposed to a broad range of geospatial technologies in a disciplinary context. While this represents progress toward meeting the need for geospatial integration, what remains is a formal assessment of student learning. In response to calls for greater accountability in higher education, and because assessment is seen as a favored method for revising teaching and improving learning (Ewell 1991), we developed a formative assessment program.

To understand how student learning, geospatial integration, and the assessments could be improved, we combined characteristics of utilization-focused and objectives-oriented assessment approaches to frame our formative assessment. It was important that we focus on our intended users and uses, as well as our outcomes and performance standards. These conceptual underpinnings drove key tasks such as identifying stakeholders, learning outcomes, potential data sources, and criteria for success. In turn, these factors influenced the development of our assessment instrumentation.

We are confident that our content analysis, which relied on categorical coding and reflection, fairly represents stakeholders' expected learning outcomes and their perspectives on geospatial integration in the NC State setting. This content analysis relies heavily on our unique understanding of our own programs and the interpretation of action words faculty used to describe desired learning behaviors. DeMers (2009) used software and a text-based approach to perform content analysis of geospatial outcomes presented in the *Body of Knowledge* (DiBiase et al. 2006). DeMers (2009) noted that it would be difficult to reproduce his study due to inconsistencies in human interpretation of key action verbs. Our content analysis could be repeated; however, results would be difficult to duplicate.

Students' deliverables were assessed to generate learning outcomes information. Forestry capstone plans demonstrated exemplary integration and application of spatial analysis and met skills-based and conceptual knowledge outcomes. However, use of the tools is a project requirement that precludes assessment of affective outcomes. The natural resources reports had almost no spatial analysis requirement; therefore, the inclusion of advanced spatial analysis was self-directed. Students' choice to use the tools is evidence of progress toward achieving desired affective outcomes. Many natural resources students exhibit social and educational characteristics Rogers (1962) ascribed to early adopters, which may explain the voluntary adoption of geospatial approaches by natural resources students.

Other assessment methods are beginning to produce useful data and show that students are benefiting from the integration of geospatial skills into existing curriculum. Lab reports that contained discussion and interpretation of analysis underlying maps were useful data sources, but students' stand-alone maps will likely no longer be collected. Assessment of lab reports from a senior forestry course show that the inclusion of a reflective piece positively impacted students' overall rubric scores. Recurring tracking questions are proving to be an efficient and effective assessment technique. Analyses of tracking data indicate that the questions are capturing changes in students' factual, conceptual, and procedural knowledge. Anderson and Krathwohl's (2001) taxonomy has proven to be a very useful 'generic' holistic rubric for assessing learning in terms of cognitive and knowledge dimension performance. Rubrics are also making it easier to evaluate students' deliverables consistently through time, which is important when comparing data across semesters.

Pre-post tests and longitudinal surveys show students are benefiting from the integration; however, many of the improvements are not statistically significant or fail to meet the intended performance standard. A survey of program graduates conducted by program administrators shows that roughly 75% are employed within their discipline. Based on job titles, only half of these within-discipline graduates appear to be likely users of geospatial technologies. In this context, failing to meet the 80% performance target does not necessarily mean students are inadequately prepared for their careers (Gary Blank, personal communication, March 1, 2012).

Due to study limitations, we chose not to directly assess affective outcomes; however, it was interesting to see them emerge in natural resource students' reports. We believe students attach value to the use of the tools when they use them by choice rather than use them to fulfill a project requirement. We are exploring the possibility surveying how graduates use or value the tools once established in their careers. The study also did not address student attainment of metacognitive outcomes. In the future, it may be constructive to document students' use of help files, internet searches, online user forums, and office hours to better understand students' self-help strategies.

2.7 Conclusions

To meet our assessment needs, we adapted concepts from a variety of assessment approaches, and our choices lead us to conceptualize a formative assessment program focused on understanding how student learning, geospatial integration, and assessment methods can be improved. Faculty and program administrator participation was essential to the process, and we enjoyed universal stakeholder buy-in. Students' willingness to participate was high, and we encountered little resistance despite participation being voluntary.

Students are benefiting from geospatial integration efforts; however, we are not meeting our intended performance targets. To improve student learning, we are revising instructional modules, adding a reflective component to assignments when possible, and working with faculty to more seamlessly integrate activities within courses in ways that complement students' ongoing coursework. We are also seeking ways to validate our data and believe that continuous outcomes monitoring will help us identify integration and assessment problems and that confidence in methodology will increase over time if the instruments continue to produce consistent data.

Many institutions have integrated geospatial instruction within their environmental resource programs. We believe an important step in advancing environmental resource and geospatial education is for colleges and universities to assess their geospatial outcomes and report their successes and lessons learned. Different institutions will undoubtedly have unique goals, needs, and circumstances, but it is difficult to benchmark performance where there is little communication of findings. The benefits of assessment can take time to be seen, but to be successful, assessments must be ongoing and sustainable (Patton 1997; Palomba and Banta 1999). Outcomes assessment represents an opportunity for wide-ranging disciplines to advance the geospatial education knowledge base.

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Table 2.1. Trends in demand for geospatial skills.

Major findings	**Study citation**
Surveys of public and private forestry related employers show they value geospatial skills and were satisfied with the abilities of their employees.	Brown & Lassoie (1998) and Sample et al. (1999)
Students returning from co-operative programs and job interviews reported employers expected candidates to possess experience using geospatial tools.	Hess & Cheshire (2002)
Labor statistics showed that demand for skilled geospatial practitioners is high and predicted to increase in the future.	US Department of Labor (2005; 2012)
A survey of 77 forestry related companies, agencies, and non-governmental organizations showed that geospatial technical knowledge is highly valued.	Kammesheidt et al. (2007)
A survey of 108 forestry and natural resources graduates from the University of Georgia showed that forty-three percent of respondents used GIS at least every other day.	Merry et al. (2007)
A survey of government agencies in North Carolina showed that at least 1,200 state employees used GIS data daily and the number of users increased dramatically when local government, private, and research communities were included.	North Carolina Office of State Budget & Management (2008)

Table 2.2. Geospatial integration in higher education.

Major findings	**Study citation**
Surveys of US and Canadian forestry schools to track changes in remote sensing education show geospatial tools and technologies were part of their educational programs.	Sader et al. (1989) and Sader & Vermillion (2000)
A survey of fisheries programs (24 respondents) showed that 96% of fisheries students were taking geospatial courses.	Fisher & Toepfer (1998)
GIS was integrated into a soil science laboratory course to demonstrate application of the tools. Students were frustrated by their inexperience with GIS but instructors planned to continue the integration with modifications.	Lee et al. (1999)
Spatial information technologies have been integrated across courses in forestry and natural resources programs and specific learning objectives have been articulated.	Hess & Cheshire (2002) and Wing & Sessions (2007)
A case study incorporating geospatial data in a land use planning course showed that students' test scores increased after the lab, and students expressed interest in taking GIS courses.	Stout & Lee (2004)
Students in two-year forestry associate degree programs used spatial analysis in their forestry, wildlife, recreation, and geography courses, were exposed to the tools during internships, and learned by helping each other.	Linehan (2006)
Evaluation of ten leading forestry programs in North America showed that all ten programs offered GIS courses and that eight programs required undergraduates to complete at least one GIS course.	Wing & Sessions (2007)
A pretest-posttest study of an undergraduate ecology laboratory showed that students' attitude declined less when GIS and field-based techniques were used in combination compared to field-based methods alone.	Simmons et al. (2008)

Table 2.3. Summary of geospatial integration in curricula and courses at NC State University, Raleigh, NC, USA.

Course	**Curriculum and class**	**Instructional opportunities**	**Course**	**Curriculum and class**	**Instructional opportunities**
Introduction to Natural Resources	all curricula freshmen	1 lecture, 1 to 3 labs	Forest Mapping and Mensuration II	Forest Management (summer camp) rising juniors	2 lectures, 3 labs
Natural Resource Measurements	Natural Resources juniors	Variable lectures, 3 labs	Forest Management	Forest Management seniors	Variable lectures, 3 to 4 labs
Environmental Impact Assessment	Natural Resources seniors	Proposed lecture and lab	Forest Inventory and Planning (capstone)	Forest Management seniors	Variable lectures, 2 labs
Natural Resource Management (capstone)	Natural Resources seniors	Varies	Wildlife Ecology and Management	Fisheries, Wildlife, & Conservation Biology, (summer camp) rising seniors	1 lecture, 2 labs
Forest Mapping and Mensuration I	Forest Management sophomores	1 lecture, 1 lab	Practice of Environmental Technology	Environmental Technology & Management seniors	Variable lectures, 2 labs

Table 2.4. The Tylerian evaluation approach. (Source: Smith and Tyler 1942; Tyler 1950)

Evaluation steps
1. Establish broad goals or objectives
2. Classify the goals or objectives
3. Define objectives in behavioral terms
4. Find situations in which achievement of objectives could be shown
5. Develop or select measurement techniques
6. Collect performance data
7. Compare performance data with behaviorally stated objectives

Table 2.5. Anderson and Krathwohl's taxonomy for learning, teaching, and assessing. (Source: adapted from Anderson and Krathwohl 2001)

	The cognitive process dimension					
The knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	*list*	*summarize*	*organize*	*classify*	*rank*	*combine*
Conceptual Knowledge	*describe*	*explain*	*demonstrate*	*differentiate*	*critique*	*propose*
Procedural Knowledge	*recall*	*generalize*	*utilize*	*distinguish*	*justify*	*develop*
Metacognitive Knowledge	*recognize*	*interpret*	*implement*	*organize*	*check*	*plan*

The italicized words inside the matrix are example key action verbs for stating desired learning outcomes.

Table 2.6. Results of structured interview content analysis.

Overall objective categories	Times mentioned	Desired learning behavior	Recurring student learning outcomes Students should possess the ability to:
Skills-Based	98	Apply and Analyze	• read, make, and communicate with maps • perform routine spatial analysis tasks • perform rudimentary spatial statistics • plan and execute a GPS field data collection mission
Factual Knowledge & Information Literacy	21	Remember, Understand, and Apply	• define and use terminology correctly • recall specific details related to the discipline • identify reliable information sources • download and organize information
Conceptual Knowledge	24	Understand and Apply	• recognize spatial problems and propose possible solutions • recognize what data and analysis techniques are needed • explain how the tools can be used together to solve problems • link the tools, fieldwork, analysis and reporting
Self-Awareness & Problem Solving (Metacognitive)	12	Understand and Apply	• recognize their own levels of understanding • identify strategies to seek help • devise strategies to solve problems
Feelings & Values (Affective)	27	Value and Characterize (Adopt and Internalize)	• willingly include geospatial approaches in their methodologies and reporting • identify use of the tools and technologies as part of becoming a resource management professional

Table 2.7. Students' deliverables collected and evaluated to generate assessment data.

Course	Maps	Reports	Projects	Management plans
Practice of Environmental Technology (seniors)	Spring 2011			
Forest System Mapping and Mensuration I (sophomores)	Fall 2010			
Forest System Mapping and Mensuration II (rising juniors)	Summer 2009 Summer 2010			
Forest Management (seniors)	Fall 2009 Fall 2010	Fall 2008 Fall 2009 Fall 2010		
Forest Inventory Analysis and Planning (capstone)	Spring 2009 Spring 2010 Spring 2011			Spring 2007 Spring 2008 Spring 2009 Spring 2010
Wildlife Ecology and Management (rising seniors)	Summer 2010			
Natural Resource Measurements (juniors)	Spring 2009 Spring 2010 Spring 2011		Spring 2008 Spring 2009 Spring 2010 Spring 2011	
Natural Resource Management (capstone)				Spring 2011
Environmental Impact Assessment (seniors)			Fall 2007 Fall 2008	

Table 2.8. Results from assessment of term projects and capstone management plans.

Course	**Class**	**Plans evaluated**	**Number of maps**	**Common analyses**	**Outcomes**
Forest Inventory and Planning	Senior capstone	5 reports from 4 semesters	6 to 37	Area Calculation Buffer/Clip Classification Overlay Sampling Selections	Skills-Based, Information Literacy, and Conceptual Knowledge outcomes were met above 80% performance standard
Natural Resource Management	Senior capstone	5 reports from 1 semester	2 to 7	Area Calculation Buffer/Clip Classification Selections	Some evidence of adoption and internalization
Environmental Impact Assessment	Senior	7 reports from 2 semesters	2 to 7	Classification Feature Extraction Sampling	Some evidence of adoption and internalization
Natural Resource Measurements	Junior	4 reports from 4 semesters	3 to 24	Area Calculation Buffer/Clip Classification Overlay Sampling Selections	Strong evidence of progress toward Skills-Based, Information Literacy, and Conceptual Knowledge outcomes

3.0 Assessing Embedded Geospatial Student Learning Outcomes

This chapter presents a manuscript entitled "Assessing Embedded Geospatial Student Learning Outcomes in Forestry and Natural Resources Curricula." The manuscript describes key steps essential to developing and implementing an assessment program. The manuscript was published in the peer-reviewed *Journal of Forestry* in 2011, and its citation is:

Carr, J.D., H.M. Cheshire, G.R. Hess, D. Bailey, and H.A. Devine. 2011. Assessing Embedded Geospatial Student Learning Outcomes in Forestry and Natural Resources Curricula. *Journal of Forestry* 109 (7):409-416.

3.1 Abstract

We developed an approach for assessing student learning of geospatial objectives embedded across undergraduate forestry and natural resources curricula at North Carolina State University. Our main goals were to characterize student attainment of geospatial outcomes and improve student learning based on those findings. Several instruments, including tracking questions, rubrics, questionnaires, and surveys were used to facilitate the process. Although initial results from a longitudinal survey show a marked increase in student exposure to and awareness of geospatial tools and technologies, tracking questions, rubrics, and questionnaires show that geospatial learning is taking place below our intended performance target. These findings have allowed us to identify avenues for improving student attainment of geospatial learning outcomes, such as articulating standard geospatial objectives, improving our assignment and instructional techniques, and establishing performance standards. The assessment methods presented could be adapted to assess aspects of other curricula and courses.

3.2 Introduction

Geospatial Information Science and Technology (GIST) refers to the study, practice, and theory of techniques, tools, and technologies that support spatio-temporal inquiry. These include geographic information systems (GIS), global positioning systems (GPS), remote sensing, cartography, spatial statistics, and database management. The depth and breadth of geosciences and how they could be integrated into higher education have been of concern to geospatial experts for some time. Although the early work of geospatial experts led to the development of model curricula for teaching geosciences in higher education, developing and assessing curricula that can accommodate the diverse user community have been long-standing challenges (Kemp and Wright 1997).

A number of studies have found high demand for geospatial skills in forestry and natural resources professions (e.g., Hess and Cheshire 2002; Kammesheidt et al. 2007; Merry et al. 2007) and undergraduate programs in forestry and natural resources are now offering and requiring a course in GIS (Wing and Sessions 2007). The Society of American Foresters *2000 Task Force Report on Forestry Education Accreditation* (SAF 2000) recommended that the ability to conduct spatial analysis and program support for spatial information technologies become accreditation standards, and later adopted those recommendations (SAF 2004). As a result, student learning outcomes assessment of geospatial objectives has become a component of North Carolina State University's (NC State) Department of Forestry and Environmental Resources (FER) curricular accreditation and instructional development processes.

Faculty at NC State teach a variety of undergraduate and graduate geospatial courses and the university offers two graduate programs and a professional certificate in geospatial information science and technology. Geospatial instructional objectives at NC State include introducing students to a broad range of geospatial tools and technologies; having students use the tools and technologies in their coursework in ways that demonstrate their practical application to forestry and natural resources issues; providing geospatial expertise and facilitating learning activities across curricula and courses; and assessing the effectiveness of the integration approach.

Although NC State offers a formal introductory GIS course, and requires it for some degree options, students need frequent exposure to geosciences and repeated hands-on use in a disciplinary context to retain what they learn. Recent findings in cognitive psychology support developing learning activities that reinforce knowledge, skills, and attitudes required to produce experienced and invested learners (Willingham 2009). To meet these needs, geospatial activities were integrated across multiple courses – exposing students to the technologies during each year of their program. One benefit of this approach is that faculty who would like to include geospatial activities in their courses are able to obtain help facilitating those activities from geospatial experts within the department. The faculty and facilitators involved with embedding geospatial outcomes across curricula and courses believe it is an effective approach for instructing students.

3.3 Study Objectives

The purpose of this study was to assess geospatial student learning outcomes across the undergraduate forestry and natural resources curricula. Our objectives were to develop a sustainable assessment approach and to apply assessments in courses that are using these technologies. Our long-term goals are to establish an ongoing assessment program that will allow us to monitor the impact of embedding geospatial technologies in undergraduate curricula, characterize student attainment of geospatial learning outcomes, and enhance student learning, specifically related to being able to choose the most appropriate use of geospatial technology in the context of real-world issues and problems.

3.4 Assessment Approach

Assessments are typically conducted for two main purposes, summative and formative. Summative evaluations are usually focused on judging the merit or worth of a program or practice (Worthen et al. 1997). Formative assessments are geared toward producing information that can be used to understand what is and is not working and why. We adopted a formative approach because we are interested in improving student learning by understanding the effects of embedding geospatial technologies across curricula.

For assessment to succeed, it must be ongoing, sustainable, and attainable (Patton 1997; Palomba and Banta 1999). This requires identifying and organizing foundational elements underpinning assessment activities. Important steps in conceptualizing an assessment include defining its purpose, identifying stakeholders, and documenting their objectives. Stakeholders with interest in this assessment include faculty and staff, students and their parents, employers, and society. We limited our stakeholder group to faculty with current or upcoming embedded geospatial activities and to FER program directors and coordinators.

3.4.1 The Assessment Framework

We collaborated with NC State University Planning and Analysis in an iterative process to develop a structured interview to solicit faculty objectives, document motives for integrating geospatial technologies and their criteria for success, and identify outcome indicators that show outcomes are being met. Hand written notes and digital recordings were taken during the interviews. The faculty interview consisted of 22 prompts and the program administrator interview consisted of 17 prompts (contact authors to obtain assessment instruments).

Faculty members who participated in the interview provided examples of observable or measurable geospatial learning outcomes. We helped them to enhance the way in which they communicate student learning outcomes in course syllabi, projects, laboratory exercises, in-class activities, and homework. Program directors and coordinators were asked to provide examples of observable or measurable geospatial outcomes at the program or curricula level.

Ten faculty and four program administrators were interviewed. The average interview lasted approximately 90 minutes. JDC performed content analysis of the audio recordings and notes taken during the interviews using a coding and memoing process (Glaser and Strauss 1967; Miles and Huberman 1994). Several objective categories and recurring themes within each category emerged (Table 3.1). Although many faculty members had clearly identifiable geospatial outcomes for their courses and assignments, geospatial outcomes were not explicitly articulated at the program or curricula level. However, program administrators routinely saw geospatial tools and technologies as essential components of broader curricular outcomes such as applying technical skills, critical thinking, problem solving, and the professional communication of information.

We analyzed participants' statements, on which the recurring themes were based, for the key action words used to describe the desired learning outcomes. These verbs were compared to word lists presented in the University of Central Florida (UCF) *Program Assessment Handbook* (Selim et al. 2006) that contain action verbs used to articulate the desired knowledge, skills, and attitudes students should possess at various performance levels. Anderson and Krathwohl's (2001) revised taxonomy of educational objectives was adapted to classify the emergent objective categories by knowledge type and cognitive process. The cognitive processes were identified by comparing action words used to describe learning outcomes to the UCF word lists. Affective domain objectives, such as students' willingness to adopt the technologies, were classified using the UCF word lists and the *Taxonomy of Educational Objectives Handbook II*: *Affective Domain* (Krathwohl et al. 1964).

Analysis of faculty and program administrator objectives revealed that overall, students should be able to: (1) apply procedural knowledge when performing skill-driven tasks, (2) understand factual and procedural knowledge related to information literacy, (3) conceptualize a role for the tools and technologies and comprehend their strengths and limitations, (4) act on their awareness of how they solve problems, and (5) value the tools and technologies and adopt their use (Table 3.1). Chapter 2 provides a detailed review of framework development, and content analysis of structured interview data.

3.4.2 Developing the Assessment Plan

Key elements of an assessment plan include identifying what, where, and how evidence of student learning will be collected, and how assessment findings will be used and reported (Palomba and Banta 1999). To ensure assessment is ongoing and sustainable, the plan should identify responsible individuals and deadlines for each task. The plan should also be able to accommodate changes in learning outcomes and instrumentation as instruction and student learning unfold through time.

We employed two broad categories of assessment methods, direct and indirect. Direct assessments require students to demonstrate their command of the desired knowledge, skills, and attitudes. Examples of direct assessments include tracking questions, laboratory exercises, projects, and questionnaires. We used a questionnaire in which students were asked factual, conceptual, and procedural geospatial knowledge questions before and after a sequence of instruction. We also used embedded assessments that evaluated student deliverables. Embedded assessments are advantageous because students generate the evidence needed to conduct assessment while performing their regular coursework (Ewell 1991; Palomba and Banta 1999).

Indirect assessments evaluate students' perceptions of their knowledge, skills, and attitudes. Examples include surveys, focus groups, and course evaluations. We used a longitudinal knowledge survey developed by Hess and Cheshire (2002) in which students reported their exposure to and awareness of geospatial technology. Students completed the survey at the beginning and end of their degree programs. Using both direct and indirect methods allows both evidence of students' learning and students' perceptions of their learning to be evaluated.

3.4.2.1 Tracking Questions

Recurring test or tracking questions are an easily implemented assessment technique. Recurring questions are minimally intrusive upon class time because they can become part of impromptu quizzes or regular exams. Student responses are used by instructors for grading purposes, and later evaluated from an assessment perspective where the criteria differ from those used for grading. While the specific wording and context of tracking questions can change semester-to-semester, the underlying objective being assessed must remain the same to preserve continuity. Tracking question data are often presented in aggregate terms, such as percent satisfactory or numbers of high, medium, and low performers.

3.4.2.2 Laboratory and Homework Rubrics

A preferred method for embedding geospatial activities across our curricula is the hands-on application of the tools and technologies to real-world problems in ways that relate to students' ongoing coursework. Our exercises typically begin with a scenario or problem statement and a list of major teaching objectives for that exercise. Students are given a set of directions they follow to arrive at a solution. Novice users are typically given a relatively complete set of data and point-and-click directions. At key milestones during the analysis, students are prompted by both the instructor and the written directions to respond to questions. The questions are designed to compel students to reflect on the meaning of what they are doing rather than blindly following the directions.

As students progress through the various stages of skill acquisition, they are given less direction and become responsible for finding or creating their own data. Deliverables, such as analysis findings presented on GIS maps, and the written interpretation and application of those findings, can be evaluated using rubrics. We used analytic rubrics to assess individual aspects of students' work and holistic rubrics to evaluate the work as a whole (Taggart and Wood 2001). Some rubrics were a simple matrix of criteria and performance level indicators for each criterion. Others rubrics required considerable development time but allow learning outcomes to be evaluated in terms of knowledge type and learning level.

3.4.2.3 Pre- and Post-Assignment Questionnaire

Several courses require a series of geospatial laboratories to meet the instructor's objectives and prepare students for course projects. This presents the opportunity for use of a pre-post design. A pre-post assignment questionnaire was developed for several courses. Students are asked factual, conceptual, and procedural geospatial knowledge questions before a sequence of instruction begins. The same questionnaire is administered several weeks after the instruction is completed. At least one weekend is allowed to pass before the same questionnaire is administered for courses offered during forestry and wildlife summer camps.

A pre-post design can be attractive because the pre-test and post-test can be compared and changes due to the educational experience inferred (Worthen et al. 1997). The questions were developed by cross-walking faculty objectives, program director and coordinator objectives, and objectives as identified in the University Consortium for Geographic Information Science *GIS&T Body of Knowledge* (DiBiase et al. 2006). Once objectives were identified and contextualized, we developed approachable questions for each knowledge area. The pre and post questions do not change and we assume students' responses will become more accurate, complete, or sophisticated after they utilize the tools.

To produce assessment data, Anderson and Krathwohl's (2001) taxonomy was used to code students' responses by knowledge type and learning level demonstrated in their responses. For example, when students' responses indicate the application of procedures to carry out familiar tasks, the taxonomy assigns codes representing the execution of specific techniques. When students' responses indicate the application of procedures to unfamiliar tasks, the taxonomy assigns codes representing a slightly higher learning level for the ability to choose and use the proper techniques for the new circumstance. Responses are tracked confidentially but individually, allowing paired before and after responses to be compared. The NC State Institutional Review Board for the Protection of Human Subjects in Research reviewed and approved the research methods and measures in place to protect study participants.

3.4.2.4 Longitudinal Knowledge Survey

Hess and Cheshire (2002) developed a longitudinal geospatial knowledge survey to track student awareness of the technologies. The surveys are intended to identify and track levels of student exposure to a variety of geospatial tools. The surveys were first administered in the fall of 2000 and are ongoing. The prior knowledge survey captures student awareness of geosciences before students are exposed to them in their coursework at NC State. The graduation knowledge survey is given to outgoing seniors and should reflect learning that occurred during their time at NC State and how their perception (valuing) of the technologies has evolved during the course of their participation in the curriculum. The longitudinal survey is also a pre-post design.

3.4.3 Application of the Assessment Plan

Applying the assessment instrumentation is an important step in determining the effectiveness of the assessment process. This should reveal how well the instrumentation captures usable information and provides insight regarding the degree to which geospatial objectives are being met. Assessment findings may also reveal how assessment criteria, outcome indicators, or methods and instrumentation can be modified or improved, and help identify specific content areas or teaching practices that need improvement.

Assessment tools were chosen based on the course, the types of activities students were engaged in, the outcomes we were attempting to observe or measure, and the resources needed to administer the assessment. To help summarize our assessment activities, we developed a simple chart that indicates what assessment methods are being implemented – or are planned for implementation – in which courses (Table 3.2). The chart also indicates the numbers of student contacts expected and the type of activities involved.

3.4.4 Initial Results from Assessments

3.4.4.1 Tracking Questions

An example from a freshman forestry and natural resources midterm exam and another from a senior environmental technology course illustrate the use of short-answer tracking questions. The freshmen-level question asks students to describe how GPS can contribute to GIS analysis in a research project. The senior-level question asks students to list ways GPS can be applied in the design and implementation of an environmental study.

The intended learning outcomes being tracked involve students remembering factual knowledge, understanding conceptual knowledge, and applying procedural knowledge. Our assessment standard is for freshmen to demonstrate that they recognize acronyms and can provide a reasonable description of how geospatial tools may be used in a project. Seniors should be able to demonstrate they possess the knowledge and experience needed to describe how to create and load sample locations onto GPS units, navigate to those locations, collect their actual field locations, transfer the data from the units, and compare their intended and actual locations.

A sample of 49 (of 106) students from the freshman course shows 67% had a satisfactory response. Evaluation of all 34 students from the senior course shows 50% had a satisfactory response.

3.4.4.2 Laboratory and Homework Rubrics

The use of rubrics is illustrated by two examples: a sophomore forestry homework assignment and a senior forestry laboratory exercise. The overall objectives of the sophomore assignment were for students to gain a concrete experience using GIS to display geospatial data by attributes and to produce a scaled thematic map layout. The homework was evaluated by course instructors using an analytic scoring rubric to generate a grade based on course-specific outcomes. A score of 13 of 15 possible points was required for students to receive a satisfactory grade. After discussing the grading criteria and point values with the course instructors, we decided that students' scores could be reused as an assessment indicator by applying a different evaluation scale (10 of 15 points). We were interested in tracking only the proportion of students who successfully displayed data by attributes and produced a scaled map layout, our objectives for the assignment, rather than grading how well they did it. A sample of 47 (of 69) students from the sophomore assignment shows that 72% used the tools successfully.

The overall objective of the senior laboratory exercise was to compare and contrast two sample-point generalization methods. Students collected field data on soil erosion, species diversity, and several habitat suitability indices. They used spatial analysis to generate an inverse-distance-weighted surface for each variable based on field observations. They also used a spatial join to calculate the stand average based on samples taken from within stands. Students were asked to provide a written comparison of the two methods and identify which generalization method was most appropriate for each type of data collected (i.e., when was it appropriate to use samples that crossed stand boundaries). In their reports, students presented maps displaying their comparisons and ancillary geospatial data that supported their interpretations (e.g., a soils map showing highly eroded inclusions at a sample site).

We reviewed 13 reports from two years (two classes), representing a total of 34 students. The reports were evaluated using a holistic rubric to generate assessment data (Table 3.3). A rubric score of ten or greater (of a maximum 16 points) was required to demonstrate the desired spatial analysis, application, and communication skills. In the first year, reports from three of six teams (of 3 - 4 students each) were satisfactory. The average rubric score was 9.8; one team scored a perfect 16. In the second year, reports from two of seven teams (of 2 students each) were satisfactory. The average rubric score was 8.3 and the highest satisfactory score was a 10. Overall performance from both years was below the performance level we expect from seniors.

3.4.4.3 Pre- and Post-Assignment Questionnaire

The pre-post assignment questionnaire has been implemented in five courses; we present results from one sophomore course as an example. On the pre-questionnaire, students self-reported they had used each technology (GPS, GIS, and air-photos or satellite imagery) an average of three times in an instructional setting. This is supported by the courses students reported they had completed previously. Seven students transferred into the program their sophomore year and missed one freshman course with embedded geospatial instructional activities. The transfer students did not indicate whether geosciences were part of their coursework at their previous institutions. Five students indicated they had completed or were currently enrolled in a semester-long introductory GIS course.

Part of the questionnaire focused on students' knowledge of basic geospatial information. One question asked students to identify sources of geospatial data. On the pre-questionnaire, 13 of 26 students (50%) were able to identify sources. On the post-questionnaire, 12 of 26 students (46%) successfully identified geospatial data sources. Four students who answered this question successfully on the pre-questionnaire failed to respond on the post-questionnaire. Three students who answered this question incorrectly on the pre-questionnaire answered correctly on the post-questionnaire. In another question, students were asked to list types of vector data. Three of 26 (12%) students were able to list points, lines, and areas as examples of vector data on the pre-questionnaire. All three students indicated they had completed or were enrolled in an introductory GIS course. Eight of 26 students (31%) were able to list points, lines, and areas as examples of vector data on the post-questionnaire.

The questionnaire also assesses students' ability to interpret spatial problems and devise approaches for applying tools to solve them. To test this, students were asked to describe in their own words how specific geoprocessing tools could be applied to forestry, natural resources, wildlife, or environmental technology data to create useful new information. Anderson and Krathwohl's (2001) taxonomy was used to classify students' responses by knowledge types and cognitive processes present in their responses. Cross-tabulation of before and after matched responses from all five courses shows more students successfully responded to the assessment question on the post-test questionnaire. Sample size is small and at least one cell in each 2x2 contingency table contains a value less than five. Therefore, Fisher's Exact Test was calculated. The chi-square statistic and *p*-value for two cross-tabulations are statistically significant at the 95% confidence level (Table 3.4). However, Fisher's Exact Test (*p*-value) is not statistically significant for any cross-tabulation at the 95% confidence level. Chapter 4 presents a detailed evaluation of student learning using pre-post assignment questionnaire data.

3.4.4.4 Longitudinal Knowledge Survey

A prior knowledge survey is given to incoming forest management and natural resources freshmen to capture the level of exposure students have to geosciences before beginning their coursework at NC State. The graduation knowledge survey is given to outgoing forest management and natural resources seniors. The survey is intended to capture how frequently students used geospatial technologies during their time at NC State and how confident they are in their own ability to use them.

Three questions were selected to demonstrate the types of assessment information the longitudinal surveys can provide. Students are asked to rate their ability to use GIS, GPS, and aerial photography or satellite imagery. A breakpoint in the response alternatives was chosen which separated respondents into two groups. The first group comprised respondents ranging from those who had never heard of the tools to those who had used them but were unsure of their abilities. The second group comprised respondents ranging from those who reported they knew how to use the tools to those who were confident in their ability to do so.

The percentage of students reporting they are able to use or are proficient with GIS, GPS, and air-photos or satellite imagery are higher in the graduation knowledge surveys (Table 3.5). Students' self-reported familiarity with GIS was consistently low on the prior-survey, ranging from 2% in 2000 to 4% in 2009. Students' self-reported use or proficiency with GIS was consistently higher on the graduation-survey, ranging from 55% in 2001 to 77% in 2010. The prior-survey indicated incoming students had a rapidly increasing familiarity with GPS (16% in 2000 to 74% in 2009) over time. The self-reported use or proficiency with GPS on the graduation-survey was fairly consistent, ranging from 55% in 2001 to 65% in 2010. The prior-survey indicated incoming students had an increasing familiarity with air-photos or satellite imagery (12% in 2000 to 25% in 2009) over time. The self-reported use or proficiency with imagery on the graduation-survey is higher, ranging from 64% in 2001 to 77% in 2010. Chapter 4 presents a detailed evaluation of student learning using knowledge survey data.

3.5 Discussion

Tracking questions in a freshman course revealed the need to encourage students to practice using geospatial terminology. We can increase our emphasis on important concepts and terms in our initial presentations and reinforce those concepts and their foundational relationships in subsequent courses. We would like our students to adopt the use of the language and believe this will result in terminology being recognized at higher rates during future evaluations. Embedding geospatial tools frequently in activities and assignments across the curricular courses facilitates this use of geospatial language. In addition to having the language of the domain in their knowledge base, they also demonstrate that they value and can use the language to communicate.

The laboratory and homework rubrics from sophomore and senior courses indicated problems with assignments. In both courses, many students failed to follow assignment directions. As a result, the geospatial elements to be assessed were missing or incomplete. To address this issue, an approach would be to provide students with a clearer articulation of our expectations, examples of what we are looking for in the final product, and a copy of the rubric used in the assessment.

The pre-post assignment questionnaires were particularly difficult to judge. The pre-post design has been criticized on a number of grounds. One critique is that participant performance on the post-test could be influenced by familiarity with the questions gained during the pre-test (Rog 1994). To counter this, we allow time to pass before administering the post-test in the hope that students do not remember the questions. Another critique is the inability to separate learning that occurs as a result of our instruction from learning that occurs through other means (Rog 1994; Worthen et al. 1997). We are focused on students' knowledge, skills, and attitudes, not necessarily where they were learned.

The questionnaires rely on students' willingness to participate in the assessment. Students are not graded on these questionnaires and may not value the information the assessments produce. We did notice that student participation was inconsistent and some students made no effort to address the questions diligently. We believe showing students that their responses have tangible results will increase the number of thoughtful responses.

Despite the critiques, the pre-post matched design is attractive because it allows for some interesting comparisons before and after an assignment. Cross-tabulations demonstrated that students failed to meet our expectations, but the tabulations consistently showed in all courses the number of students who can successfully answer questions about spatial analysis increased after an embedded geospatial activity.

The longitudinal survey results showed that students consistently reported an increase in their abilities at the end of their academic programs. This survey also suffers from some of the same problems as the pre-post assignment questionnaire. It is not possible to separate learning that occurs as a result of geospatial integration from learning through other means. Although respondents typically answer more honestly on self-administered surveys and questionnaires than during interviews, they still commonly over-report socially desirable outcomes (Dillman 2000). We do not know if students are over-reporting their exposure to and comfort using geospatial tools and technologies on the graduation survey because they believe that is the expected response. However, the survey data document a ten-year record of student use and awareness of geospatial tools.

An issue that is beginning to affect the longitudinal survey is the extension of GPS and digital imagery technologies into daily life. Anecdotal evidence (conversations with students) suggests increases in students' self-reported use or proficiency with GPS and digital imagery is due in part to technologies such as in-car navigation systems, GPS enabled smart phones, and internet mapping tools such as MapQuest and Google Earth. This may be beneficial to student learning. If students see value in how they use the technologies in their personal lives, they may be willing to explore how the tools are employed in their chosen field more deeply. However, the increasing presence of the technologies is affecting our ability to assess our programs with the survey. We are considering revising the survey to address this concern.

3.6 Conclusions

Novice learners can follow a set of directions and produce a result, but the knowledge necessary to know when and why to use the tools is more conceptually and experientially driven (Schön 1987). Systematic and strategic assessment of geospatial technology integration is important because it allows us to monitor how students are progressing toward those understandings.

Our instructional activities follow Kolb's (1984) experiential learning model. The learning approach results in an experience students can reflect on; repeated exposures help students retain knowledge gained from these experiences. We also believe that by embedding geosciences across curricula and courses, students begin to view geospatial technologies as a necessary tool and not an end in itself.

We have integrated geospatial tools and technologies into a variety of courses. The assessment instruments used in this study have been adaptable to the diverse subject matter and teaching practices we encounter. We believe the approaches we use – including tracking questions, rubrics, questionnaires, and surveys – are flexible enough to accommodate our assessment needs. Initial results are inconsistent, but provide a baseline for future assessments.

One of the greatest benefits of initiating a more formal assessment has been working more closely with faculty to understand their objectives, allowing us to fully integrate course content, geospatial technologies, and real-world problems. This has heightened student awareness of geospatial technologies as tools to consider rather than a body of knowledge separate from the focus of their courses. Other stakeholders, including employers and parents, are looking for concrete evidence that graduates are prepared for their careers. While we focused on faculty and program administrators as the stakeholders in this analysis, it is reasonable to assume that other stakeholders would be interested in the assessment findings. Expanding our approach to include other stakeholder groups is a future consideration.

We plan to continue improving our assignments, teaching practices, and our assessments. We believe our embedded assignments are exposing undergraduates to a broad range of geospatial tools, technologies, and their uses. We feel they are providing students with an awareness of geospatial information and analysis tools they can use to better understand and assess environmental phenomena. Our assessments are allowing us to monitor student learning and improve our teaching. Moreover, we believe the assessment approaches presented here could be helpful to others developing assessments for their courses and curricula.

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Table 3.1. Geospatial objectives that emerged from analysis of structured interviews and response themes common among faculty and program administrators.

Emergent objectives	**Common response themes**
Task related skills	• must be able to make and read maps • can perform geoprocessing and spatial analysis • possess ability to create a sample plan suitable for field work
Information literacy	• can identify information sources on their own • demonstrate ability to download and manage their own data • recognize what data are needed and can find them
Conceptual knowledge	• explain how the tools are used together to create and analyze data • understand the uses and limits of the technologies • see links among tools, field work, analysis and reporting
Metacognitive knowledge	• when stuck, students know enough to help themselves • can ask the appropriate questions • can identify the right strategies
Affective domain	• willingness to adopt the use of the technologies • have awareness and actually consider using the tools • recognize they are going to use it in life after school

Table 3.2. Implementation chart showing which assessment methods are in use or planned for each course with an embedded geospatial component.

Course	**Instructional opportunities**	**Rubrics for assignments**	**Tracking questions**	**Pre-post assignment questionnaire**	**Capstone project rubrics**	**Longitudinal knowledge surveys**
Introduction to Natural Resources	1 lecture, 1 to 3 labs		Implemented			Implemented
Forest Mapping and Mensuration I	1 lecture, 1 lab	Implemented	Planned			
Forest Mapping and Mensuration II	2 lectures, 3 labs	Planned	Planned	Implemented		
Natural Resource Measurements	Variable lectures, 3 labs	Planned		Implemented		
Wildlife Ecology and Management	1 lecture, 1 lab	Planned		Implemented		
Natural Resource Management (capstone)	Varies				Planned	Implemented
Forest Management	Variable lectures, 4 to 5 labs	Implemented		Implemented		
Forest Inventory and Planning (capstone)	Variable lectures, 2 labs				Planned	Implemented
Practice of Environmental Technology	Variable lectures, 2 labs		Implemented	Implemented		
Environmental Impact Assessment	Proposed lecture and lab				Planned	

Table 3.3. Rubric used to generate assessment data from senior forestry spatial analysis lab reports.

Student performance (16 points possible)	**Weak** 0 points	**Good** 1 point	**Very good** 3 points	**Excellent** 4 points
Surface interpolation	response does not indicate why sample locations were or were not included in the analysis	response does indicate an understanding of how sample-points are being used	tradeoffs are addressed by example using data e.g., discussion of “continuous” elevation data	argues that landscape features provide ecosystem services that are dynamic and often follow a continuous data model i.e., no hard boundary
Averaging by stand	response does not indicate why sample locations were or were not included in the analysis	response does indicate an understanding of how sample-points are being used	tradeoffs are addressed by example using data e.g., discussion of “discrete” GPS positions	argues that discrete management units are necessary in order to implement recommendations so boundaries must be delineated somewhere
Overall feature symbolization and cartographic representation	poor color selection; data not classified in a thoughtful way; missing map elements; improper legend names	data classified thoughtfully; no missing map elements; no improper names in the legend	pattern and color selections mimic characteristics of the features they represent; map is well organized	transparency used to depict spatial interaction among features; a truly ‘polished’ map
Intended use and audience appropriateness of maps	map is not appropriate for intended use e.g., unusable scale on field map; the audience is not actively targeted e.g., use of jargon on maps intended for laypersons	map is appropriate for intended use; audience is actively targeted; purpose of map is not readily apparent	purpose of map is somewhat apparent; map requires some explanation by author	purpose of map is apparent; map requires no explanation by author

A rubric score of ten or greater is required to satisfactorily meet the desired performance standard for this assessment.

Table 3.4. Cross-tabulation of matched before and after student responses to a geospatial application and analysis question on the pre-post assignment questionnaire.

Course	Number pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	Chi-square statistic	Calculated *p*-value	Fisher's exact test
Practice of Environmental Technology (2010)	30	6	1	1	22	0.852	0.356	0.418
For. System Mapping and Mensuration II (2009)	24	8	3	0	13	4.052	0.044*	0.082
For. System Mapping and Mensuration II (2010)	15	7	1	1	6	0.010	0.919	1.000
Forest Management (2008)	10	3	5	0	2	2.500	0.114	0.444
Forest Management (2009)	12	5	6	0	1	1.091	0.296	1.000
Wildlife Ecology & Management (2010)	34	16	8	0	10	4.359	0.037*	0.072
Natural Resource Measurements (2010)	23	10	2	0	11	2.008	0.156	0.478

*Calculated *p*-value for two cross-tabulations is statistically significant at the 95% confidence level ($\alpha = 0.05$).

Table 3.5. The percentage of students reporting they are able to use or are proficient with GIS, GPS, and air-photos or satellite imagery from selected years of the longitudinal knowledge survey.

	Prior knowledge survey				**Graduation knowledge survey**			
Year	Fall 2000	Fall 2003	Fall 2006	Fall 2009	Spring 2001	Spring 2004	Spring 2007	Spring 2010
Respondents (*n*)	57	52	38	84	33	19	40	26
GIS	2%	0%	5%	4%	55%	74%	65%	77%
GPS	16%	17%	32%	74%	55%	74%	73%	65%
Imagery	12%	13%	18%	25%	64%	79%	65%	77%

4.0 Assessing Geospatial Learning Outcomes: Results and Lessons Learned

4.1 Abstract

Geospatial instructional activities have been integrated across curricula and courses in the Department of Forestry and Environmental Resources at North Carolina State University. To evaluate success of the integration, we developed an outcomes-based framework to assess student learning. Pre-post tests were used to determine if students' geospatial knowledge and skills changed after course-embedded activities. Longitudinal knowledge surveys were used to determine if students' awareness of and confidence in their ability to use the tools changed over the course of their programs. The assessments showed that student knowledge increased after course-embedded activities; however, many improvements were not statistically significant or failed to meet the intended performance target. Students' awareness and confidence were significantly increased at the completion of their programs, but the overall percentage of students reaching the study's identified objectives fell short of the performance target. Students generally had more success with frequently repeated material, and students in curricula with more integration reported higher levels of awareness and confidence. The assessments have helped us identify instances where there were instructional missteps and unforeseen issues with assessment methods and provided us with baseline student learning data. Better geospatial integration within curricula and courses will improve learning, and we are working with faculty to design course-embedded activities that effectively complement students' ongoing coursework.

4.2 Introduction

Geospatial technologies are essential research and planning tools for effective monitoring and management of our natural resources. In response to adoption of the tools by environmental professionals, colleges and universities have incorporated spatial information technologies within their forestry and natural resources degree programs (Sader and

Vermillion 2000; Hess and Cheshire 2002; Merry et al. 2007; Wing and Sessions 2007). The Society of American Foresters adopted “spatial analysis” as a forestry program accreditation standard (SAF 2004), and the University Consortium for Geographic Information Science developed the *GIS&T Body of Knowledge* (DiBiase et al. 2006) which articulates example geospatial learning outcomes. These factors, in addition to calls for greater academic accountability (e.g., Cook et al. 2006; Prager and Plewe 2009), inspired our efforts to formally articulate geospatial learning outcomes and assess how well they were being met.

US Department of Labor statistics show that demand for skilled geospatial practitioners is high and predicted to increase in the future (DOL 2005). A survey of government agencies in North Carolina showed that at least 1,200 state employees used geospatial data daily, and the number of users increased dramatically when local governments were included (OSBM 2008). Industry surveys show that public and private forestry related employers value geospatial skills (Brown and Lassoie 1998; Sample et al. 1999; Kammesheidt et al. 2007), and a survey of 108 forestry and natural resources graduates from the University of Georgia found that forty-three percent of respondents used geospatial technologies in their work at least every other day (Merry et al. 2007).

Studies have been conducted to document the extent of geospatial integration into higher education programs (e.g., Fisher and Toepfer 1998; Sader and Vermillion 2000; Merry et al. 2007; Wing and Sessions 2007), and faculty have incorporated spatial information technologies into a variety of courses (e.g., Lee et al. 1999; Stout and Lee 2004; Linehan 2006). Hess and Cheshire (2002) developed a set of specific geospatial outcomes for forestry and natural resources programs at North Carolina State University (NC State), and Wing and Sessions (2007) identified specific learning objectives for a geospatial forest engineering course at Oregon State University.

Geoscience-enriched learning opportunities have been integrated within the Forest Management and Natural Resources curricula at NC State for the past two decades. More recently, integration efforts have expanded to include the Fisheries, Wildlife, & Conservation Biology and the Environmental Technology & Management curricula. Hess and Cheshire (2002) described specific integration objectives for the Department of Forestry and Environmental Resources, including (1) exposing students to geospatial technologies in each year of their programs, (2) providing technical support for the development and implementation of geospatial activities in undergraduate courses, and (3) evaluating the effectiveness of the approach. Now, geospatial experts within the department help faculty design and facilitate instructional activities that range from one-time immersions to semester-long projects. The purpose of the integration is to expose students to real-world application of spatial information technologies in a disciplinary context. Use of the tools is hands-on, repeated across multiple courses, and linked to students' ongoing coursework.

Stakeholders (e.g., employers, program administrators, and accrediting bodies) are demanding greater academic accountability and that student learning be documented (Cook et al. 2006; Prager and Plewe 2009), and outcomes assessment has come to be viewed as a favored method for improving learning (Ewell 1991). Little has been published reporting on student attainment of geospatial outcomes and what could be done to improve student learning. The purpose of this study was to assess student attainment of geospatial learning outcomes, identify possible avenues for improving learning, and evaluate the effectiveness of the integration approach.

Our objectives were to:

(1) determine if students' skills-based, information literacy, and conceptual knowledge changed after course-embedded geospatial activities and met the intended performance target;
(2) determine if students' awareness of and confidence in their ability to use geospatial technologies changed over the course of their program and met the intended performance target; and

(3) compare student performance by semester, course, and curriculum to identify any instructional or instrumentation problems, determine if students are consistently exposed to the technologies, and to determine if higher levels of integration lead to increased knowledge and awareness.

4.3 Methods

4.3.1 Identifying Geospatial Outcomes

Our first step was to identify the outcomes to be assessed. We worked with NC State University Planning and Analysis to develop structured interviews that we administered to faculty who taught course-embedded geospatial activities and program administrators in the department. The NC State Institutional Review Board for the Protection of Human Subjects in Research reviewed and approved research methods and measures in place to protect study participants' privacy and organizational intellectual property. One of us (JDC) performed content analysis of interview audio recordings using categorical coding methods adapted from Glaser and Strauss (1967) and Miles and Huberman (1994).

Content analysis of interviews with faculty revealed five objective categories and several recurring student learning outcomes (Table 4.1). Bloom's (1956) taxonomy was used to assign performance levels to skills-based, information literacy, and conceptual knowledge outcomes based on key action verbs participants used to describe the desired learning. Krathwohl's (1964) taxonomy was used to classify action verbs associated with affective outcomes (feelings and values), and metacognitive outcomes (awareness of one's own knowledge and cognition) were classified using Anderson and Krathwohl's (2001) taxonomy.

Interview participants were asked to identify where evidence of learning could be observed or measured. Faculty indicated that student learning could be tested directly or expressed through students' maps, reports, and presentations. Participants were also asked what criteria or standards would characterize successful geospatial integration. A plurality indicated a reasonable initial performance target would be for 80% of students to satisfactorily meet each learning outcome.

4.3.2 Assessing Student Knowledge and Skills

To determine if students' knowledge and skills changed after a series of course-embedded activities, we developed a pre-post test (Appendix C). Test questions assessed skills-based, information literacy, and conceptual knowledge outcomes identified during the content analysis of structured interview data. Test questions were cross-walked with the *GIS&T Body of Knowledge* (DiBiase et al. 2006) and covered seven of ten knowledge areas. Students in participating courses completed the pretest prior to being involved with any geospatial activities in their courses. At the conclusion of instructional activities, time was allowed to pass (two to three weeks) before students completed the posttest. The pre-post test was administered in multiple courses and years (Appendix D).

Two types of geospatial knowledge questions – list and discussion – were included on the pre-post tests, along with demographic questions. All knowledge question responses were coded as either correct (1), or incorrect (0) – questions with no response were coded as incorrect. List questions were used to determine if students recognized terminology or could recall factual knowledge. A predetermined number of responses was used to determine if students satisfactorily answered list questions. For example, students needed to list at least two vector data types (point, line, or area) for a response to be coded as correct.

Discussion questions challenged students to describe the application of spatial concepts and analysis techniques (e.g., discuss how the buffer and clip tools can be used in combination to perform a natural resource management task). Anderson and Krathwohl's (2001) taxonomy was used to evaluate students' responses. The taxonomy organizes learning behaviors in terms of knowledge types (factual, conceptual, procedural, and metacognitive), and cognitive processes (remember, understand, apply, analyze, and evaluate). Satisfactory discussion question responses were answers that communicated a conceptual understanding of the question and applied reasonable procedures to address the problem.

In each course, individual students' pre-post test responses were tracked using a unique identifier. To test for changes in knowledge and skills, students' pretest and posttest responses to each question were compared using contingency tables (crosstabs). McNemar's (1947) tests were used to determine if any differences identified in the crosstabs were significant. When McNemar's test detected a significant difference, the crosstab counts indicated whether students performed better on the pretest or posttest.

An overall performance variable was calculated by tallying the number of correct responses for each participant for each test. Students' overall pretest knowledge and overall posttest knowledge were compared using Wilcoxon's (1945) signed-rank tests to determine if there were differences. When a significant difference was detected, the mean ranks indicated whether students' overall performance was better on the pretest or posttest.

To determine if outcomes met intended performance targets, the total number of correct responses for each posttest question was divided by the total number of respondents (percent satisfactory). If the percent satisfactory was greater than or equal to the 80% performance target, the outcome represented by that question was considered met for that course that year. Percent satisfactory was averaged by question so strengths and weaknesses in students' knowledge could be identified. Percent satisfactory was also averaged by course so performance among courses could be compared.

4.3.3 Assessing Student Awareness and Confidence

During the structured interviews, many faculty indicated that students should be aware of geospatial tools and technologies and their application to resource management issues. To track students' awareness of and confidence in their ability to use geospatial technologies, Hess and Cheshire (2002) developed two knowledge surveys. An incoming survey, first administered in the fall of 2000, is completed before students are exposed to geospatial technologies in their coursework (Appendix E). An outgoing survey, first administered in the spring of 2001, is given to seniors as they near completion of their capstone course (Appendix F).

The surveys capture students' self-reported awareness of and confidence in three geospatial technologies: geographic information systems (GIS), global positioning systems (GPS), and aerial photography and satellite imagery. The surveys contain a variety of questions including demographics (e.g., what is your major), frequency of geospatial technology use, and whether or not students enjoyed using the technologies. Students' incoming and outgoing surveys were to be matched using a unique identifier; however, the university adopted a different student identification system in 2004, thus interrupting the ability to match all surveys. Matching surveys and surveys that could not be matched were analyzed separately because it can be statistically advantageous to include pretest data when possible (Bonate 2000), and we were unsure if the two samples were comparable.

Preliminary analyses included plotting incoming and outgoing survey question responses by response frequency. Median and mode response levels were also calculated. Wilcoxon's (1945) signed-rank tests were used to determine if students' awareness and confidence changed for matching incoming and outgoing surveys. Non-matching data were grouped into intervals of incoming and outgoing surveys to roughly approximate time to graduation, and to account for changes in students over time (Table 4.2). To determine if students' awareness and confidence changed, these grouped data were compared using Wilcoxon's (1945) rank-sum tests.

The response scale for awareness and confidence questions had six alternatives ranging from never having heard of the technologies (response alternative 1) to considering oneself a very proficient user of the tools (response alternative 6). Two response alternatives (5 and 6) satisfactorily met the desired awareness and confidence criteria for the GIS, GPS, and imagery questions. To determine if the overall performance target (≥80%) was met, for each technology, the number of satisfactory responses was divided by the number of respondents (percent satisfactory) and compared to the standard.

4.3.4 Performance by Semester, Course, and Curriculum

Outcomes monitoring is important to assessment because it can help identify problems (Affholter 1994) and consistent data can increase confidence in methodology (Carter 1994). To identify instructional or instrumentation problems and to see if students were being consistently exposed to geospatial technologies, we compared overall pretest, overall posttest, and gain scores (overall posttest - overall pretest) for courses with two or more semesters of pre-post test data using Wilcoxon’s (1945) rank-sum tests.

Levels of geospatial integration vary among curricula and courses. Curricula and courses with more integration or learning opportunities should perform better than those with less. To detect any course-to-course differences, overall pretest, overall posttest, and gain scores were analyzed using rank-sum tests for two group comparisons. The first group comparison was between two senior courses with different integration levels: Practice of Environmental Technology and Forest Management. The second group comparison was between two junior courses with different integration levels: Natural Resource Measurements and Wildlife Ecology & Management.

To determine if student awareness and confidence differed among participating curricula, outgoing survey responses were analyzed using Kruskal-Wallis (1952) tests. All response alternatives were considered in the analysis. If the Kruskal-Wallis test indicated that a difference existed, rank-sum tests were performed to identify which curricula were different on which questions.

4.4 Results

4.4.1 Changes in Knowledge and Skills

Crosstabs and McNemar's tests were repeated for each year each course participated in the pre-post test assessments (Appendix G). The analysis showed that posttest scores were consistently higher than pretest scores, and 34% (24 of 70) of the improvements were statistically significant. A detailed example of results comes from a junior-level course, Natural Resource Measurements (Table 4.3). In this example, students' responses to five of seven knowledge questions were significantly different from pretest to posttest. Crosstabs showed that the direction of change was from incorrect on the pretest to correct on the posttest. Crosstabs also identified an instructional concern. Despite significant improvement, 16 of 23 students were unable to provide examples of raster data on the posttest, even with instructional emphasis on raster data and analysis that semester.

To determine if overall performance was significantly different from pretest to posttest for each course and year, signed-rank tests were performed. The analysis of overall scores showed all ten pre- and post-assessments were significantly different at the 95% confidence level (Table 4.4). In every case, the mean ranks indicated that students performed better on the posttest.

Eight of 70 questions (seven knowledge questions repeated across ten courses) met the faculty's 80% performance target (Appendix H). The average of student performance by course showed upperclassmen slightly outperforming underclassmen. The average of student performance by question showed the most frequently repeated material and activities outperforming important but less frequently repeated material. Overall performance was highest on the map elements (73%), spatial analysis (59%), and vector data (58%) questions – tasks related to these outcomes recur in almost all geospatial activities. Overall performance was lowest on the raster data (32%), and GPS data collection (30%) questions – tasks related to these outcomes recur in fewer activities.

4.4.2 Changes in Awareness and Confidence

Of 641 incoming and 389 outgoing knowledge surveys, seventy-five student's surveys could be matched. Because the number of matches was small, all years of matching data were analyzed together. Cumulative response alternative percentages (response frequency divided by the number of respondents) showed that students were more aware and confident on outgoing surveys (Figure 4.1). Median and mode responses were generally two response alternatives higher on outgoing surveys (Table 4.5). Signed-rank tests of matching data showed that student awareness and confidence were significantly higher on outgoing surveys for all three technologies (GIS $p < 0.001$, GPS $p < 0.001$, imagery $p < 0.001$; $\alpha = 0.05$).

We also examined survey data for which before and after responses could not be matched. The cumulative response alternative percentages for non-matching data showed that students were more aware and confident on outgoing surveys (Figure 4.2). Rank-sum tests showed awareness and confidence were significantly higher for all three technologies in each analysis interval of data (GIS $p < 0.001$, GPS $p < 0.001$, imagery $p < 0.001$; $\alpha = 0.05$). The median and mode responses were three response alternatives higher for GIS, and two response alternatives higher for imagery on outgoing surveys (Table 4.5). For GPS, incoming and outgoing mode response alternatives were the same, and the outgoing median was one response alternative higher than incoming.

Increasing awareness and confidence on incoming surveys indicate that students are exposed to GPS and digital imagery before they enter their programs (Figure 4.3). GPS responses have risen sharply in recent years, and imagery responses have slightly increased. Satisfactory responses on outgoing surveys showed a marked increase for GIS and imagery questions compared to the incoming surveys (Figure 4.3). Incoming GPS responses were higher than outgoing responses in 2009 (9% higher), and in 2010 (8% higher).

Percent satisfactory was calculated and compared to the intended performance target (Table 4.5). Matching outgoing survey performance came close to meeting the performance target for all three technologies (GIS 77%, GPS 76%, and imagery 77%). Non-matching outgoing survey performance fell below the performance target for all three technologies (GIS 68%, GPS 69%, and imagery 67%).

4.4.3 Differences by Semester, Course, and Curricula

Rank-sum tests of pre-post test performance between semesters of the same course identified three significant differences at the 95% confidence level (Appendix I). In 2011, students in Practice of Environmental Technology scored better on both the pretest (p = 0.001) and posttest (p = 0.019) than they did in 2010. In 2011, students in Natural Resource Measurements scored better on the posttest (p = 0.047) than they did in 2010. Rank-sum tests for the between-course group comparisons identified three significant differences at the 95% confidence level (Appendix J). In 2010, Forest Management students performed better than Practice of Environmental Technology students on the pretest (p = 0.003). In 2010, students in Wildlife Ecology & Management performed better than Natural Resource Measurements students in 2011 on the posttest (p = 0.043) and in gain scores (p = 0.038).

Fisheries, Wildlife, & Conservation Biology; and Environmental Technology & Management programs are relatively new to the integration and assessments and were excluded from curricular comparisons using matching survey data due to the small number of respondents. Rank-sum tests of matching data showed Forest Management (n = 34) and Natural Resources (n = 26) students' awareness and confidence were not significantly different at the 95% confidence level for GIS (p = 0.142) and imagery (p = 0.813), but Forest Management students' self-reports were significantly higher for GPS (p = 0.010).

Rank-sum tests of outgoing non-matching data showed Forest Management students' self-reported awareness and confidence were significantly higher than Natural Resources students at the 95% confidence level on the GIS ($p = 0.032$) and GPS ($p = 0.035$) questions (Appendix K). Forest Management students' self-reports were significantly higher than Fisheries, Wildlife, & Conservation Biology students on the GIS ($p < 0.001$) and imagery ($p < 0.001$) questions. Forest Management students' self-reports were also significantly higher than Environmental Technology & Management students on the imagery question ($p = 0.046$).

Natural Resources students' self-reports were significantly higher than Fisheries, Wildlife, & Conservation Biology students on the imagery question ($p = 0.008$). Environmental Technology & Management students' self-reports were significantly higher than Natural Resources students on the GPS question ($p = 0.007$). Environmental Technology & Management students' self-reports were significantly higher than Fisheries, Wildlife, & Conservation Biology students on the GIS question ($p = 0.001$).

The original intent was to analyze meaningfully paired data; however the low match rate prompted us to compare outgoing matching, outgoing non-matching, and combined outgoing data using rank-sum tests. Although the mean ranks and overall performance for each technology question changed, there were no statistically significant differences among the three datasets, and the same curriculum-to-curriculum significant differences persisted.

4.5 Discussion

Increased knowledge and skills on pre-post tests show students are affected positively by course-embedded activities. Although only 34% of the improvements were statistically significant for individual questions, we now have information and methods we can use to target and monitor instruction in underperforming content areas. Upperclassmen outperformed freshmen and sophomores, and courses with more geospatial learning opportunities performed better than those with less. Students in all courses performed better on questions related to the most frequently repeated material. For example, students were typically required to make a map at the conclusion of each embedded activity. Overall, students achieved 73% success on the mapping outcome. Raster analysis and GPS data collection are common instructional topics, but they are repeated less than map making. Students achieved 32% and 30% success on the raster and GPS outcomes respectively. These findings are supported by literature on the value of targeted, repeated practice (Ambrose et al. 2010).

Pre-post test assessments are producing consistent data and are helping us identify instructional problems. Significant semester-to-semester differences for the same course only occurred when a semester with an instructional or assessment misstep were compared to a semester with no such issues. Examples of missteps included attempting more material than time allowed, failing to cover a key topic due to an oversight or needed focus on other topics, or students' failing to answer assessment questions diligently. Similarly, the course-to-course group comparisons were only significantly different when a course that encountered an instructional or assessment issue was compared to one that had not encountered a problem. Geospatial facilitators were aware of these missteps when they occurred, and we believe the effects of these events are reflected in the data.

Small sample size and item nonresponse are affecting some assessments. For example, during the 2009 offering of Forest System Mapping & Mensuration II, students' responses to 5 of the 7 geospatial knowledge questions were significantly improved. The following year, students in the same course only demonstrated significant improvement on one question. Learning outcomes, instructors, teaching approach, and contact hours were the same both years, and students seemed equally talented and willing to work. We believe the lack of statistical significance the second year is related to the small number of students enrolled in the course in 2010 (n = 15 matching pre-post tests) and item nonresponse (skipping a question). In 2010, a few blank posttest responses from students who responded correctly on the pretest made statistical significance difficult to achieve. It should be noted that both offerings of the course showed significant posttest improvement in overall learning, and there was no significant difference between the two courses in overall learning.

We believe item nonresponse and students' failing to answer assessment questions diligently (e.g., "great lab the other week" or "my computer froze") is reducing the number of statistically significant improvements. Response issues seem to be more prevalent on the posttest, and when students are enrolled in more than one course with assessments. It is unclear how to separate a lack of knowledge from a refusal to respond, and dismissing incomplete cases or substituting missing values can result in bias (de Leeuw et al. 2003; Davidian et al. 2005). To address item nonresponse, we explain to students how these data are actually being used, and are pilot testing facilitating assessments online while in class; however, some stakeholders have expressed reservations about moving away from paper questionnaires.

Few of the pre-post knowledge questions met the 80% performance target. The performance target is a goal to strive toward, and despite its somewhat arbitrary nature (a compromise among wide ranging views held by faculty), it is a standard against which performance data can be objectively evaluated. It is unclear if failure to meet our performance targets reflects instructional and integration issues, or instrumentation and participation limitations. A combination of factors undoubtedly contributes to the low performance numbers and we view the findings as a baseline from which to improve rather than an indicator of program success.

Increased awareness and confidence self-reports on longitudinal surveys show students are successfully exposed to GIS, GPS, and imagery in their programs. Outgoing awareness and confidence for matching data were close to meeting the intended performance target for all three technologies, indicating that students perceived confidence in their abilities. Different programs have different levels of integration to meet faculty's needs and program objectives, and the analysis did show some curriculum-to-curriculum differences. The Forest Management program has somewhat higher levels of integration than other programs, and 5 of 8 significant differences in awareness and confidence involved forestry students' self-reports. The Natural Resources program has the second highest level of integration and natural resources students' self-reports were higher than Fisheries, Wildlife, & Conservation Biology; and Environmental Technology & Management. It should be noted, self-reports reflect students' perceptions of what they know or do not know, and may not reflect actual understanding of the question or material.

Incoming GPS awareness and confidence are quite high in recent years. We believe the prevalence of in-car navigation systems, smart phone technology, and recreational grade GPS devices is reflected in incoming responses. It can be beneficial to course and program outcomes if incoming students are aware of how they consume geospatial technologies in their daily lives. This may make students receptive to learning how the tools are used by professionals. However, this trend will eventually prevent comparison of incoming and outgoing survey responses, and the survey questions may need to be modified.

One approach to mitigating recent trends in incoming GPS and imagery awareness is the retrospective pretest (Campbell and Stanley 1966; Pratt et al. 2000). In this approach, outgoing seniors would be asked to self-report their awareness and confidence as they approach completion of their program, and what they perceived it to be when they began their program. This method may result in students feeling the need to demonstrate increased knowledge on outgoing surveys, but would eliminate change in one's understanding of a question as they learn more about the topic. The approach would also reduce loss of participants through changes in majors, transfers, and attrition.

Loss of participants and changes in the student identification system contribute to the low match rate (20%) for longitudinal knowledge surveys. We believe some students are not comfortable sharing their information – which is handled confidentially through an

Institutional Review Board approved process – and others simply may not remember or incorrectly report their identification information. Rank-sum tests of incoming matching and non-matching data showed the two groups were significantly different on incoming GIS and imagery awareness and confidence. However, analysis of outgoing matching, outgoing non-matching, and pooled outgoing data showed these were not significantly different. Because outgoing responses were consistently significantly improved compared to incoming responses, the ability to match surveys is historically low, and comparisons of matching and non-matching outgoing data were not significantly different, it is not necessary to match incoming and outgoing surveys and posttest only analysis of pooled outgoing data may be an alternative for future assessments.

The exercises and instructional approaches faculty employ are not static. We do not view this as an impediment to assessment because the geospatial learning outcomes we integrate and assess are foundational and change more gradually. Based on assessment findings, we seek to inform those changes in content, presentation, assignments, and assessments. To evaluate student learning from multiple perspectives we developed a variety of assessment instruments. Chapter 2 presents an analysis of students' maps, lab reports, term projects, and capstone course management plans, and Carr et al. (2011) provides an overview of assessment methods and their implementation.

4.6 Conclusions

The assessments show students' knowledge and skills, and awareness and confidence are benefiting from geospatial integration. Curricula and courses we have been working with the longest have more instructional opportunities and the most seamless integration into ongoing coursework. We believe better integration leads to adoption of spatial analysis as a routine problem solving approach and deepen student learning. Students' awareness and confidence will increase over time because more curricula and courses are choosing to integrate geospatial technologies, making it likely that students will encounter the tools frequently.

We are working with faculty to identify opportunities for improving course-embedded activities by revising instructional modules and making them more meaningful and complementary to students' ongoing coursework. Integrating geospatial activities is often demanding of class time, leaving little room for reflection. We have observed how a reflective piece at the conclusion of spatial analysis activities deepens learning, and we intend to add a reflective piece to our instruction when possible.

Although it is difficult to disentangle knowledge students gain from curricula and courses from other learning, the assessments are producing baseline student learning information we can use to objectively evaluate both student performance and our performance as educators. Outcomes assessment is seen as the path to academic improvement. The direct impacts of assessment on student learning can be unclear (Hutchings and Marchese 1990), and they take a long time to be seen (Palomba and Banta 1999). While many benefits of assessment seem elusive, geospatial facilitators, faculty, and administrators are working closely together as a result of the assessments. These partnerships will likely lead to future synergies and collaborations that will improve instructional processes and student learning.

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Table 4.1. Results of structured interview content analysis.

Overall objective categories	**Times mentioned**	**Desired learning behavior**	**Recurring student learning outcomes** Students should possess the ability to:
Skills-Based	98	Apply and Analyze	• read, make, and communicate with maps • perform routine spatial analysis tasks • perform rudimentary spatial statistics • plan and execute a GPS field data collection mission
Factual Knowledge & Information Literacy	21	Remember, Understand, and Apply	• define and use terminology correctly • recall specific details related to the discipline • identify reliable information sources • download and organize information
Conceptual Knowledge	24	Understand and Apply	• recognize spatial problems and propose possible solutions • recognize what data and analysis techniques are needed • explain how the tools can be used together to solve problems • link the tools, fieldwork, analysis and reporting
Self-Awareness & Problem Solving (Metacognitive)	12	Understand and Apply	• recognize their own levels of understanding • identify strategies to seek help • devise strategies to solve problems
Feelings & Values (Affective)	27	Value and Characterize (Adopt and Internalize)	• willingly include geospatial approaches in their methodologies and reporting • identify use of the tools and technologies as part of becoming a resource management professional

Desired levels of performance are based on action verbs from taxonomies of educational objectives (Bloom et al. 1956; Krathwohl et al. 1964) and Anderson and Krathwohl's (2001) taxonomy.

Table 4.2. Intervals of non-matching incoming and outgoing knowledge survey data.

Interval	**Incoming year**	***n***	**Outgoing year**	***n***
1	2000, 2001	101	2004, 2005	41
2	2002, 2003	115	2006, 2007	57
3	2004, 2005	66	2008, 2009	39
4	2006, 2007	61	2010, 2011	118*

*The increased number of outgoing respondents in years 2010 and 2011 is due to additional curricula participating in the assessments.

Table 4.3. Cross tabulation and McNemar's tests of students' pre-post test responses. (Natural Resource Measurements, spring 2010)

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	23	9	10	2	2	0.065	83%†
List three types of vector data	23	10	3	0	10	0.002*	57%
List two examples of raster data	23	6	1	0	16	0.031*	30%
Discuss the relationship between scale and resolution	23	7	4	3	9	0.344	48%
Compare two GPS data collection methods	23	10	2	0	11	0.002*	52%
Describe an application of the buffer and clip tools	23	10	2	0	11	0.002*	52%
List five essential map elements	23	9	4	0	10	0.004*	57%

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

†The number of correct posttest responses divided by the total number of posttest respondents was greater than the faculty's 80% performance target.

Table 4.4. Overall pretest and posttest scores from the pre-post test assessments.

Course, **year**	***n***	**Scored better on pretest**	**Pretest mean ranks**	**Scored better on posttest**	**Posttest mean ranks**	**Scored same on pre and post**	***p*-value**
Practice of Environmental Technology, 2010	30	2	10.75	23	13.20	5	< 0.001*
Practice of Environmental Technology, 2011	22	2	3.50	14	9.21	6	0.001*
Forest System Mapping & Mensuration II, 2009	24	2	5.00	19	11.63	3	< 0.001*
Forest System Mapping & Mensuration II, 2010	15	0	0.00	10	5.50	5	0.004*
Forest Management, 2008	12	1	2.50	7	4.79	4	0.027*
Forest Management, 2009	12	1	3.00	9	5.78	2	0.011*
Forest Management, 2010	18	3	5.00	10	7.60	5	0.031*
Wildlife Ecology & Management, 2010	33	1	4.50	28	15.38	4	< 0.001*
Natural Resource Measurements, 2010	23	1	3.00	18	10.39	4	< 0.001*
Natural Resource Measurements, 2011	27	0	0.00	23	12.00	4	< 0.001*

*Overall pretest and posttest mean ranks were significantly different at the 95% confidence level ($\alpha = 0.05$).

Table 4.5. Summary statistics for matching and non-matching knowledge surveys.

	Incoming survey questions			Outgoing survey questions		
Matching surveys	**GIS**	**GPS**	**Imagery**	**GIS**	**GPS**	**Imagery**
Median response alternative	3	4	3	5	5	5
Mode response alternative	2	3	3	5	5	5
Percent Satisfactory (response alternatives five and six)	12%	42%	30%	77%	76%	77%
Non-matching surveys	**GIS**	**GPS**	**Imagery**	**GIS**	**GPS**	**Imagery**
Median response alternative	2	4	3	5	5	5
Mode response alternative	2	5	3	5	5	5
Percent Satisfactory (response alternatives five and six)	5%	41%	19%	68%	69%	67%

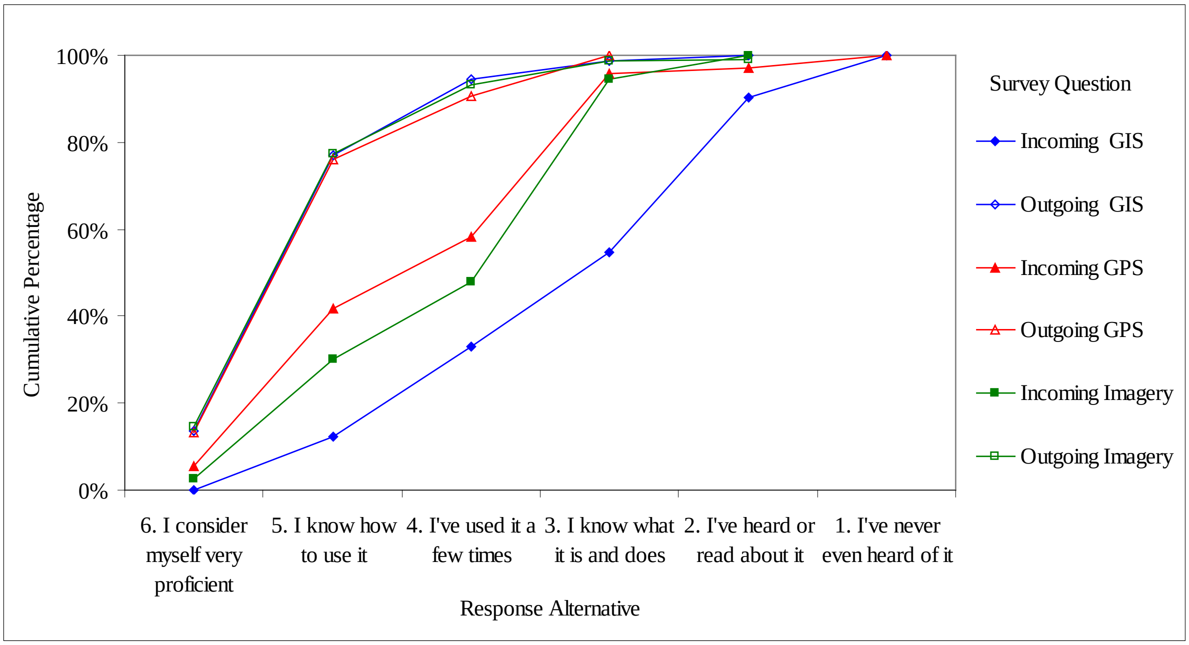

Figure 4.1. Cumulative response alternative percentages for matching incoming and outgoing longitudinal knowledge surveys. Approximately 77% of matching students reported they knew how to use (response alternative 5) or considered themselves proficient at using (response alternative 6) GIS, GPS, and digital imagery on outgoing surveys.

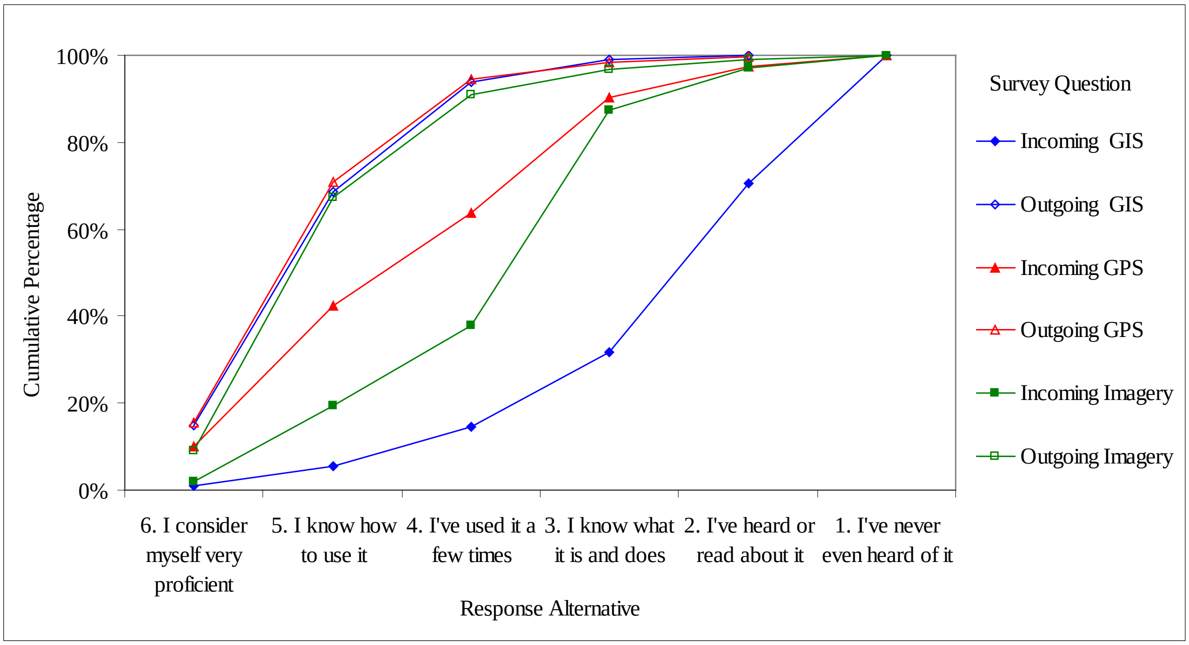

Figure 4.2. Cumulative response alternative percentages for non-matching incoming and outgoing longitudinal knowledge surveys. Approximately 69% of non-matching students reported they knew how to use (response alternative 5) or considered themselves proficient at using (response alternative 6) GIS, GPS, and digital imagery on outgoing surveys.

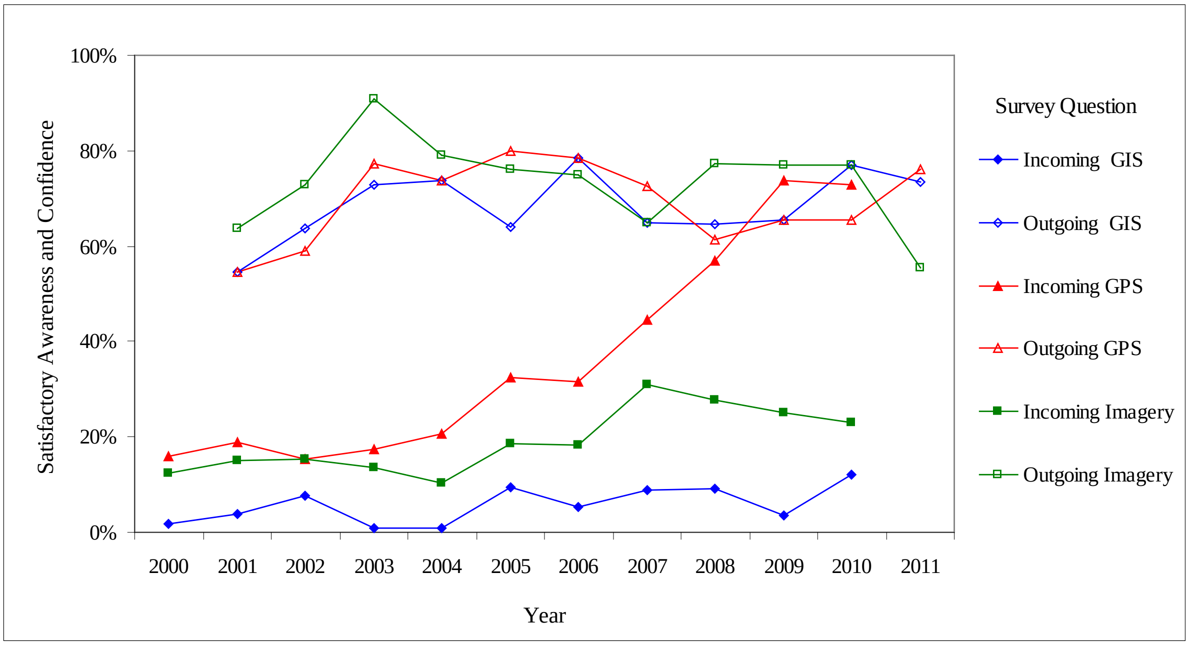

Figure 4.3. Percent satisfactory (number of satisfactory response alternatives divided by the number of respondents) awareness and confidence for incoming and outgoing knowledge surveys. The number of satisfactory responses is generally higher on outgoing surveys.

5.0 Conclusions

In this study we investigated student attainment of geospatial learning outcomes by developing and implementing outcomes-based assessments. The first objective was to develop an assessment framework (Chapter 2). The framework identified foundational elements underpinning assessment activities allowing assessment theory to be made operational. The second objective was to plan, develop, and test assessment methods (Chapter 3). Multiple methods and measures were developed to evaluate student learning from a variety of perspectives. The third objective was to report results of the assessments and comment on the current state of student learning (Chapter 4). Many colleges and universities have integrated geospatial sciences within their programs; however, we found no published reports of geospatial outcomes attainment. This study contributes to that knowledge base, and findings and recommendations for eight specific research questions are summarized below.

5.1 Findings

1. What are Department of Forestry and Environmental Resources stakeholders' intended geospatial student learning outcomes? and *2. What is the desired learning level for each outcome?* Faculty and administrators in the department, our primary stakeholders, participated in structured interviews to identify intended geospatial learning outcomes, where to look for evidence of learning, and criteria for success. This information was a foundation for the development of assessment methods and guided their implementation. Content analysis of interview data showed that faculty and administrators' viewpoints on the purpose of integration fell into two categories. Some believed integration should expose students to the technologies, making them aware of how the tools can contribute to resource management. Others believed students should acquire geospatial skills and abilities and be able to perform spatial analysis tasks.

The interviews resulted in the identification of five objective categories and a number of recurring student learning outcomes. Participants routinely described skills-based, information literacy, conceptual knowledge, and metacognitive outcomes. Faculty desired that outcomes be met at the application and analysis levels in taxonomies of educational objectives (e.g., Bloom et al. 1956; Anderson and Krathwohl 2001). Participants also expected affective outcomes (Krathwohl et al. 1964), and wanted students to accept, value, and internalize spatial analysis as part of becoming a natural resource professional. Participants' responses were used to identify an initial performance target (80% satisfactory) for the assessments.

3. Where can evidence of the desired learning behavior be observed or measured? and *4. What assessment methods are appropriate for capturing and analyzing evidence of learning?* Faculty and administrators indicated that they believe evidence of student learning was observable through students' classroom behavior and participation, and measurable through students' coursework and testing. In response, direct assessment methods were developed to assess skills-based, information literacy, and conceptual knowledge outcomes. Direct assessments included recurring tracking questions, pre-post tests, and evaluation of students' deliverables with rubrics. A longitudinal knowledge survey developed by Hess and Cheshire (2002), an indirect assessment method, was used to assess students' awareness of and confidence in their ability to use geospatial technologies (i.e., exposure). In addition to producing assessment data, we gained insights into the value and logistics associated with each assessment instrument.

Tracking questions were used to monitor skills-based and conceptual knowledge outcomes in a freshman natural resources course and in a senior environmental technology course. This method required coordination with instructors because test questions and dates frequently change. When a question changes, the new question must assess the same outcome and instruction must target the same learning level if the intent is to compare outcomes attainment over time. For these assessments, percent satisfactory was calculated and tracked. Criteria for a satisfactory response generally followed faculty's grading criteria.

Students' maps were collected at the completion of each course-embedded activity. The intended use was to determine if students could perform spatial analysis and communicate effectively with maps. Students' maps did not prove to be a useful source of assessment data. Most maps appeared rushed and only indicated that students participated in a geospatial activity. Exceptions to this included maps that were generated during class time where map making was a key objective, maps that were assigned as homework, and maps presented in lab reports that contained an explanation of the underlying analysis. These maps were successfully evaluated with rubrics. Unless specific uses are identified, it may not be necessary to continue collecting and archiving students' maps from all activities.

Students' term projects and capstone management plans were evaluated using taxonomies of educational objectives for skills-based, information literacy, and conceptual knowledge outcomes. Term projects from a junior natural resources course show strong progress toward meeting desired outcomes. However, students work in specialized teams and it is unlikely that the geospatial abilities demonstrated in the reports represent the groups' abilities. Forestry seniors demonstrated superb integration, application, and communication in their capstone management plans; however, use of the tools was required and students were provided with examples of expected maps and analyses.

Natural resources capstone management plans lacked a sufficient geospatial component for geospatial outcomes assessment. The only geospatial requirement was an overview map of the study area using prepared data provided by the instructor. However, natural resources students demonstrated affective outcomes by choosing to incorporate spatial analysis into their capstone management plans even though it was not required. Natural resources students also demonstrated affective outcomes in another senior course by choosing to use the tools in their environmental impact assessment reports. Many natural resources students exhibited characteristics Rogers (1962) ascribes to “early adopters” and should be encouraged to use the technologies. We should approach faculty who teach these two senior natural resources courses to discuss the possibility of more formally integrating geospatial outcomes into senior projects.

Pre-post tests were used to assess skills-based, information literacy, and conceptual knowledge outcomes before and after course-embedded activities. Pre-post tests established a baseline for student knowledge and abilities and produced information on the impacts of course-embedded instructional activities. In every case, overall posttest knowledge was higher than overall pretest knowledge. In several cases, posttest item nonresponse from participants who responded correctly on pretests negatively affected results. Possible causes of nonresponse include students failing to see value in assessment and students feeling overly assessed. It is unclear how more diligent responses can be obtained because participation is voluntary; however, to address item nonresponse, we explained to students how these data are actually being used and are pilot testing facilitating assessments online during class time. To reduce the assessment burden on students, posttest only methods should be considered for future assessments. If a new instructional approach were introduced, pre-post tests could be conducted to evaluate the effectiveness of the approach.

Longitudinal knowledge surveys also followed a pre-post design and were used to assess students’ self-reported geospatial awareness and confidence. The surveys document students’ perceptions of what they know or do not know and produce information related to students’ exposure to the technologies. Future assessments should use the surveys as presented in Appendices E and F in which demographic question wording and sequencing have been standardized. The ability to match surveys is historically low, and comparisons among matching, non-matching, and combined outgoing datasets were not significantly different, so it may no longer be necessary to match incoming and outgoing surveys. Posttest only analysis of all outgoing surveys or retrospective pretest methodologies (e.g., Campbell and Stanley 1966; Pratt et al. 2000) may be viable alternatives for future assessments.

Question 5: *How well are geospatial student learning outcomes being achieved?* Faculty that guided the assessments have high expectations, and integration failed to meet several learning outcomes and most performance targets identified in the structured interviews. However, geospatial integration has been successful, likely satisfies facilitators' learning outcomes (Table 1.3), and results in increased student learning. These assessments show students' ability to use the technologies increased after instructional activities, and students were more aware and confident at the completion of their programs. However, the state of student learning outcomes attainment is mixed.

Each instrument has strengths and weaknesses and contributes to our understanding of outcomes attainment. Some instruments evaluate the same outcomes using different information and methods (e.g., students' deliverables and pre-post tests) while others evaluate different aspects of the integration (e.g., longitudinal surveys versus capstone management plans). Some instruments indicate high levels of outcomes attainment, while others indicate much lower levels. These data are complementary and can be used in combination (i.e., "triangulation") to more completely understand assessment information and characterize student learning (Caudle 1994; Worthen et al. 1997; Palomba and Banta 1999).

For example, pre-post test data and lab reports for Forest Management show students performed below intended performance targets. However, the same students' capstone management plans demonstrate exemplary integration and application of the technologies. This implies that several measures from different contexts are needed to characterize students' knowledge and abilities. The ability of these students to integrate spatial analysis into their management plans despite low performance on other assessments shows strong problem solving and self-help skills.

Faculty identified metacognitive outcomes as an important objective category; however, we chose not to formally assess students' problem solving and self-help strategies due to time and resource limitations. If the number of questions on either the knowledge survey or pre-post test could be prioritized and reduced, there may be room to add questions related to students' use of instructional modules, help files, internet searches, online user forums, other students, and office hours. We also chose not to formally assess student attainment of affective outcomes. While affective outcomes emerged from natural resource students' capstone management plans and impact assessment reports, it may not be possible to measure long-term adoption and internalization on campus. A survey of program graduates could be used to solicit information on whether and how they value geospatial education after they are established in their careers.

Question 6: *How can student learning be improved?* Curricula and courses we have been working with the longest have more instructional opportunities and the most seamless integration into ongoing coursework. Longitudinal survey data show that students' self-reports were consistently higher for curricula with more learning opportunities than those with less. This suggests that greater and more seamless integration will increase students' awareness and confidence. Findings from pre-post tests were less clear. In general, courses with more integration performed better on spatial analysis questions than those with less, and upperclassmen generally outperformed underclassmen. Students in all curricula and courses performed better on questions related to the most frequently repeated material. This shows frequent exposure with repeated hands-on use in a disciplinary context leads to learning. These findings are supported by literature on the value of targeted, repeated practice (Ambrose et al. 2010). Pre-post test findings can be used to identify underperforming content areas so instructional efforts can be prioritized based on student performance and stakeholder objectives.

Reflection is an important instructional technique that should be implemented widely. Most course-embedded activities leave little or no time for students to reflect on what they have done and why. We have observed how a reflective piece at the conclusion of spatial analysis activities deepens learning and a reflective piece should be added to assignments when possible. Students frequently produce maps at the conclusion of instructional activities. Maps and lab reports from three semesters of the same activity in a senior forestry course were evaluated with rubrics. The assessments show that students benefited more from pasting screenshots of analysis results into a word processor and writing a few sentences contrasting the various analysis methods than they did designing presentation quality maps. Because time is limited and facilitators may not have the authority to assign homework, some end-of-activity map making could be substituted with a reflective piece focused on what the technologies brought to bear on the issue at hand.

Question 7: *How can geospatial integration be improved?* Effects of implementing instructional changes are often subtle and can take a long time to be seen. Many key benefits of assessment stem from how it causes faculty to think about their teaching and how they work with others (Palomba and Banta 1999). The assessments show repeated exposure that complements students' ongoing coursework leads to improved learning. Therefore, we should work with faculty to identify opportunities to increase the number of course-embedded activities and revise existing activities to make them more seamlessly integrated with ongoing classroom activities. The number of curricula and courses with embedded geospatial activities has increased since the assessments began, and student learning should improve over time because it is likely they will encounter the tools more frequently.

Question 8: *How can the assessments be improved?* Assessment instruments are continually refined and are producing consistent information from a variety of sources. Since the assessments began we have improved the wording of assessment questions based on student feedback and preliminary analysis, refined rubrics used to evaluate deliverables, reported findings to stakeholders, and made recommendations to them based on those findings. The assessments have helped us identify instructional and assessment process mistakes. For example, there have been occasions where students were burdened with too many assessments or facilitators attempted to cover more material than time allowed. Teaching practices were altered in response; however, it is unclear how to reduce assessment burdens. One alternative, which was suggested for the pre-post tests and longitudinal surveys, would be to transition to posttest only methods.

Assessment requires significant effort on the part of students, faculty, and facilitators, and any payoff can be a long-term investment. These assessments are not sustainable. One avenue for making the assessments more sustainable would be to prioritize and reduce the number of questions on the pre-post tests and longitudinal surveys. For example, longitudinal survey questions related to whether students like working with geospatial technologies or how frequently they use email or word processing software may not be vital information. The reductions would make room for other program or course outcomes to be added to existing instrumentation. These modifications could garner wider support and participation that would contribute to the sustainability of the assessments.

One assessment alternative would be to develop an e-portfolio approach. As students progress through their programs, they develop skills, experiences, and beliefs. By the end of their programs, students should be able to identify spatial questions and perform spatial analysis to accomplish their work efficiently. Digitally stored artifacts of learning could be used to document students' progress toward achieving these learning goals. This type of approach would also provide students with reflective self-assessment opportunities helping them understand their own learning, and could be used to evaluate learning outcomes at the course and curriculum levels (Lorenzo and Ittelson 2005).

5.2 Recommendations

Hutchings and Marchese (1990) state that it would be difficult, at best, to show a clear link between assessment and improved learning, and Angelo and Cross (1993) suggest that any perceived increase in learning may be an artifact of new information generated about processes that were already ongoing. However, the assessments described here are producing baseline student learning information that we can use to objectively evaluate both student performance and our performance as educators, allowing us to make informed choices for future instruction and curricular development.

General recommendations emerged from this study including the following suggestions:

- Revise existing learning opportunities making them more complementary to ongoing coursework
- Revise existing learning opportunities targeting underperforming knowledge areas
- Develop new integration opportunities in participating courses (e.g., NR 400)
- Develop new integration opportunities in nonparticipating courses (e.g., FW 453, ET 201)
- Explore content changes in geospatial related courses:
    - FOR 353 exchange a photogrammetry lab for a GIS or GPS lab
    - ET 252 exchange a GIS lab for a raster data lab
    - GIS 410 incorporate GPS data and concepts in lectures and homework
- Explore support for and steps needed to develop e-portfolio assessment approaches
- Develop surveys to explore employer satisfaction with program graduates' geospatial skills, and how those graduates value their own geospatial education (affective outcomes)

Specific recommendations emerged from this study including the following action items:

- Cease collecting and archiving students' maps produced at the conclusion of course-embedded activities unless specific assessment uses are identified in advance
- When appropriate, add a reflective piece at the conclusion of course-embedded activities in lieu of map making
- Transition pre-post tests and longitudinal knowledge surveys from hardcopy to online facilitation methods
- For courses with pre-post tests, adopt posttest only methods
- Longitudinal knowledge surveys should be revised:

- Remove questions that are not collecting vital information (e.g., how frequently students use email or word processing software, or how well students liked working with the technologies)
- Add a question to document geospatial related courses students have had or are taking (e.g., GIS 410, ET 252, FOR 353)
- Add a question to document students' self-help and problem solving strategies (metacognitive outcomes)
- Analyze pooled (matching and non-matching) outgoing data for future assessments

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APPENDICES

Appendix A. Faculty Structured Interview Questions

Purpose

The purpose of the structured interviews is to solicit the following information from faculty who have invited us to integrate geospatial instructional interventions within their course(s): (1) what are your broad geospatial objectives, (2) why have you chosen to incorporate geospatial activities in your class, (3) what do you want students to be able to do, (4) what are your assessment criteria for success, and (5) what types of outcome indicators provide evidence that criteria are being met.

Background

Date:
Name:
Title:
Course(s):

Integration

1. Why did you choose to include geospatial material in your course(s) (e.g. work efficiently, ask new questions, hirable skill, think differently, etc.)?

2. How many activities in your course(s) include a geospatial component (e.g. they work with maps and photos all the time)?

3. How is the relevant geospatial material introduced to your students (e.g. traditional lectures and labs, group activities, collaborative learning projects, etc.)?

4. How many formal geospatial lectures, labs, homework, projects, etc. are there?

5. Describe the integration of geospatial material with other course material (e.g. the instruction complements students' ongoing coursework vs. the exercises are stand alone)?

6. How does this integration support or interfere with your overall course goals?

Objectives and Student Learning Outcomes

7. Please list the overall geospatial objectives for your course(s) (i.e. the geospatial knowledge, skills, abilities, values and attitudes should students possess upon completing your course)?

8. Please rank the objectives identified above.

9. For each assignment with a geospatial component, please describe your geospatial objectives?

10. Have you articulated specific student learning outcomes for objectives at either the course or assignment levels?

Criteria and Indicators

11. What types of outcome indicators would be required to provide evidence of student learning for the objectives identified above?

12. What would appropriate performance standards for each objective look like (e.g. 85% of 6th graders are reading at grade level)?

13. What types of criteria would characterize a successful integration of geospatial material within the course?

Assessment

14. What types of information (formal or informal) do you collect or observe which give you insight regarding the degree to which students are achieving the intended geospatial outcomes (test questions, lab reports, map layout rubrics, etc.)?

15. Give examples of all the methods you use to evaluate students in your course(s).

16. How do you separate an individual’s performance from group work (e.g. writer writes the report, mensuration person does field work, GIS person makes the map, etc.)?

Pros and Cons

17. Do you believe embedding geospatial material within course activities is an appropriate and effective technique for meeting your geospatial objectives (or should students take a geospatial course)?

18. Have you observed any negative impacts on course-specific learning as a result of including geospatial material in your course (e.g. reading the recipe vs. understanding what is being done to the data)?

19. Have you observed any positive impacts on course-specific learning as a result of including geospatial material in your course?

20. How could the integration of geospatial material in your course(s) be improved? What obstacles have you encountered and what are your ideas on how to remove those obstacles?

Wrap-up

21. What did we miss or fail to ask?

22. Do you have any questions for me?

Appendix B. Program Administrator Structured Interview Questions

Purpose

The purpose of the structured interviews is to solicit the following information from Forestry and Environmental Resources program directors and coordinators: (1) what types of assessment processes are in place for each curriculum, (2) how active are those processes, (3) how do geospatial tools and technologies support program level objectives, and (4) what types of assessment criteria and outcome indicators are needed at the program level to demonstrate student performance.

Background

Date:
Name:
Title:
Program:

Assessment Environment

1. Describe any assessment activities in response to external accrediting bodies (e.g. SACS, Society of American Foresters, National Recreation and Park Association).

2. Describe any assessment activities in response to college or university requirements (e.g. Undergraduate Program Review, General Education Assessment).

3. Describe the program's assessment process and documentation.

4. How active is the program's assessment process?

5. What types of assessment data (portfolios, grades, tracking questions, rubrics, etc.) are collected and how are they used (analyzed, aggregated) and reported?

6. Please respond to the following statements: The program is an aggregate of the curricula, which are an aggregate of courses, which are an aggregate of lessons. Student performance at the program level can be aggregated this way.

Objectives and Student Learning Outcomes

Below are two outcomes for the Natural Resources curricula.

Students should demonstrate the ability to:

- assess natural resources effectively using appropriate methods and technologies.
- communicate proficiently in the kinds of writing and speaking required of natural resource professionals.

7. Do you think it is appropriate for geospatial teaching and assessment advocates to read geospatial outcomes into curricular outcomes?

For example, students should demonstrate the ability to:

- use appropriate methods and technologies includes GIS, GPS, air photo, etc.
- communicate proficiently and professionally includes maps and layouts.

8. Program outcomes must be described broadly to cover the scope of the entire program. Which of your program's outcomes are potentially complemented by geospatial instruction?

9. Are you aware of any course-embedded geospatial activities supporting curricular outcomes for your program?

10. What types of geospatial knowledge, skills, abilities, values and attitudes should students possess upon graduation? What are the program's geospatial objectives?

11. Please rank the objectives identified above.

Criteria and Indicators

12. What types of outcome indicators would be required to provide evidence of student performance for the objectives identified above?

13. What would appropriate performance standards for each objective look like (e.g. 85% of 6th graders are reading at grade level)?

14. What types of criteria would characterize a successful integration of geospatial material within the program?

Wrap-up

15. Does the inclusion of geospatial material support or enhance the program? If so how (e.g. work efficiently, ask new questions, hirable skill, think differently, etc.)?

16. What did we miss or fail to ask?

17. Do you have any questions for me?

Appendix C. Pre-Post Test Assessment

Geospatial Information
Science and Technology
Pre-Post Assignment Questionnaire
Spring/Fall 20xx, Course xx xxx

The purpose of this survey is to help us assess the effectiveness of our efforts to teach geographic information science and technology, including geographic information systems (GIS), global positioning systems (GPS), and image interpretation (photogrammetry and remote sensing). We will use this survey to uncover how much you already know about geospatial information tools, technologies and their uses. Follow-up surveys will be used to help us measure how much you've learned about geographic information science and technology during your time at NC State.

These surveys will in no way affect your grades and we ask that you please be completely candid and thorough in your responses. Survey results will only be reported for groups regarding broad trends. Individual responses will be held in strict confidence. Please do not consult anyone as you complete this questionnaire.

Please write your student ID number here ______________________.

We will not identify individuals or their responses under any circumstances. However, we would like to compare your responses across prior and post surveys. **This information is very important in helping us improve our geographic information science and technology programs.**

Thank you for your time and consideration in completing this questionnaire!

First, we need to know a few things about you to better understand your responses.

1. Which of the following courses have you previously completed or are currently enrolled?
For each, please check the box that applies

	Never Taken	Currently Enrolled	Previously Completed
NR 100 or FOR 110 (Introduction to Natural Resources or Forestry)			
FOR 172 (Forest Mapping & Mensuration I)			
FOR 273 (Forestry summer camp)			

	Never Taken	Currently Enrolled	Previously Completed
ET 252 (Introduction to Spatial Technologies)			
NR 300 (Natural Resource Measurements)			
FW 311 (Fisheries & Wildlife summer camp)			
FOR 405 (Forest Management)			
GIS 410 or GIS 510 (Introduction to Geographic Information Systems)			
ET 460 (Practice of Environmental Technology)			

2. Did you transfer into your Department of Forestry & Environmental Resources program?
___ Yes ___ No

If yes, please identify the institution, transfer semester and year?_____________________

3. Please describe how frequently you have used each of the following spatial technologies.
For each, please circle the most frequent category that applies.

	Never	1 - 2 times	3 - 4 times	5 - 6 times	More than 6 times
GIS	1	2	3	4	5
GPS	1	2	3	4	5
Air-photos or Satellite Imagery	1	2	3	4	5
Other (specify __________)	1	2	3	4	5

Geospatial data for laboratory exercises and coursework are often given to you. The following question is intended to determine if you know where you would go to find geospatial data if they were not provided.
Please fill in the appropriate blanks.

4. List three sources for obtaining existing geospatial data.

____

____

____

Two basic geospatial data types are vector data and raster data. The following questions are intended to assess your knowledge of how these datatypes represent geospatial features differently.
Please fill in the appropriate blanks.

5. List the three different types of vector data.

____

____

____

---

6. Give two examples of raster data.

____

____

Scale is a property inherent in geospatial data. **The following question is intended to assess your knowledge of how scale impacts geospatial data and analysis**.
Please answer in the space provided below.

7. In your own words, give an example of why or when you would represent the same geospatial feature(s) at different scales or resolutions.

GPS can be used to collect or verify locational data. **There are several different methods for collecting features with GPS**. **The following question is intended to assess your knowledge of when to use two different GPS data collection methods**.
Please answer in the space provided below.

8. In your own words, give an example of why or when you would collect a GPS line feature using a dynamic technique versus using vertex averaging.

In GIS, **it is common to apply tools in succession to accomplish an analysis task**. **The following question is intended to assess your knowledge of how to apply two of the most common GIS tools in succession to solve a problem**.
Please answer in the space provided below.

9. In your own words, give a forestry, natural resources, fisheries and wildlife, or environmental technology example of how the Buffer tool and Clip tool can be used in succession to perform an analysis task.

Map layouts are convenient and effective planning and communication materials. **The following question is intended to assess your knowledge of basic map-making principles**.
Please answer in the space provided below.

10. Please list 5 of the 8 essential map layout elements.

______________________ ______________________

______________________ ______________________

____

Embedded Assessment Questions

11. Discuss two ways GIS can be used to aid in the design and implementation of an environmental assessment.

12. Discuss two ways GPS can be used to aid in the design and implementation of an environmental assessment.

Thank you for completing this questionnaire!

Appendix D. Pre-Post Test Assessment Participants

Courses	**Years**
Practice of Environmental Technology (seniors)	Spring 2010 Spring 2011
Forest System Mapping & Mensuration II (rising juniors)	Summer 2009 Summer 2010
Forest Management (seniors)	Fall 2008 (questionnaire pilot test) Fall 2009 Fall 2010
Wildlife Ecology & Management (rising seniors)	Summer 2010
Natural Resource Measurements (juniors)	Spring 2010 Spring 2011

The pre-post test assessments were administered before and after series of geospatial instructional activities in multiple courses and years.

Appendix E. Incoming Knowledge Survey

Department of Forestry & Environmental Resources
Spatial Information Technology
Prior Knowledge Survey
Spring/Fall 20xx, Course xx xxx

The Department of Forestry and Environmental Resources is administering this survey to help us evaluate the effectiveness of our efforts to teach spatial information technologies, including geographic information systems, global positioning systems, and image interpretation. We will use this survey to learn how much you already know about spatial information technologies and computers. Future surveys will help us measure how much you've learned about spatial information during your time at NC State.

These surveys will in no way affect your grades, and we ask that you please be completely candid in your responses. Results will be reported only for groups — individual responses will be held in confidence. Please do not consult anyone as you complete the survey.

Please write your student ID number here ______________________.

Although we will not identify individual responses, we would like to compare your responses across multiple surveys. **This information is very important to the Department and will help us improve our programs. THANK YOU for your time!!**

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1. Do you know what a geographic information system (GIS) is?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of GIS. (*Skip to Question 4*)
   2. I've heard or read about GIS, but I don't know what it is. (*Skip to Question 4*)
   3. I know what a GIS is and does, but have never used one. (*Skip to Question 4*)
   4. I've used GIS a few times, but don't really know what I'm doing. (*Continue with Question 2*)
   5. I know how to use a GIS. (*Continue with Question 2*)
   6. I consider myself very proficient with GIS. (*Continue with Question 2*)

2. During the past year, how frequently have you used geographic information systems (GIS) in each of the following contexts?
   For each, please circle the most frequent category that applies.

	Never	Less than once a month	About once a month	About once a week	Daily
a. Job or internship	1	2	3	4	5
b. Course or workshop	1	2	3	4	5

c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

3. Overall, how did you like working with GIS?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

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4. Do you know what a global positioning system (GPS) is?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of GPS. (*Skip to Question 7*)
   2. I've heard or read about GPS, but I don't know what it is. (*Skip to Question 7*)
   3. I know what a GPS is and does, but have never used one. (*Skip to Question 7*)
   4. I've used GPS a few times, but don't really know what I'm doing. (*Continue with Question 5*)
   5. I know how to use a GPS. (*Continue with Question 5*)
   6. I consider myself very proficient with GPS. (*Continue with Question 5*)

5. During the past year, how frequently have you used global positioning systems (GPS) in each of the following contexts?
   For each, please circle the most frequent category that applies.

	Never	Less than once a month	About once a month	About once a week	Daily
a. Job or internship	1	2	3	4	5
b. Course or workshop	1	2	3	4	5
c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

6. Overall, how did you like working with GPS?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

---

7. Do you know what aerial photography or satellite imagery are?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of them. (*Skip to Question 10*)
   2. I've heard or read about them, but I don't know what they are. (*Skip to Question 10*)
   3. I know what they are, but have never used them. (*Skip to Question 10*)

4. I've used them a few times, but don't really know what I'm doing. (*Continue with Question 8*)
5. I know how to use aerial photography or satellite imagery. (*Continue with Question 8*)
6. I consider myself very proficient with aerial photography or satellite imagery. (*Continue with Question 8*)

8. During the past year, how frequently have you used aerial photography or satellite imagery in each of the following contexts?
   For each, please circle the most frequent category that applies.

	Never	Less than once a month	About once a month	About once a week	Daily
a. Job or internship	1	2	3	4	5
b. Course or workshop	1	2	3	4	5
c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

9. Overall, how did you like working with aerial photography or satellite imagery?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

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10. Please indicate about how often you have used the following types of software / technologies within the past year.
    Please circle the most frequent level that applies.

Software	Never	Less than once a month	About once a month	About once a week	Daily
a. Word processing	1	2	3	4	5
b. Spreadsheet	1	2	3	4	5
c. Electronic mail	1	2	3	4	5
d. World Wide Web	1	2	3	4	5
e. File downloads	1	2	3	4	5
f. Digital photography	1	2	3	4	5

11. Overall, how comfortable are you with computers, software, and technology?

Not at all	Only a little	Somewhat	Comfortable	Very Comfortable
1	2	3	4	5

Finally, we need to know a few things about you, to better understand your responses.
Please circle the appropriate response for each question.

12. To what extent did a desire for training in spatial information technologies influence your decision to major in Forestry, Natural Resources, Fisheries and Wildlife, or Environmental Technology?

Not a major	Not at all	Only a little	Somewhat	A good deal	A lot
0	1	2	3	4	5

13. Do you expect to use spatial information technologies in your career?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

14. Your sex.

    1. Male
    2. Female

15. Your year.

    1. Freshman
    2. Sophomore
    3. Junior
    4. Senior
    5. Graduate Student
    6. Other

16. Your age.

    1. 18 or younger
    2. 19
    3. 20
    4. 21
    5. 22
    6. 23 or older

17. Did you transfer into a Department of Forestry & Environmental Resources program?

    1. No

2. Yes, from within NC State
3. Yes, from another school

18. What curriculum are you in?

1. Forest Management
2. Natural Resources Ecosystem Assessment
3. Natural Resources Policy and Administration
4. Environmental Science: Watershed Hydrology
5. Fisheries, Wildlife, and Conservation Biology
6. Environmental Technology and Management
7. Graduate Student
8. Other

Thank you for completing this survey.

Appendix F. Outgoing Knowledge Survey

Department of Forestry & Environmental Resources
Spatial Information Technology
Graduation Knowledge Survey
Spring/Fall 20xx, Course xx xxx

The Department of Forestry and Environmental Resources is administering this survey to help us evaluate the effectiveness of our efforts to teach spatial information technologies, including geographic information systems, global positioning systems, and image interpretation. We will use this survey to learn how much you have learned about, or been exposed to, spatial information technologies and computers in your curriculum. Over the next several years, information from these surveys will be compared to surveys completed by incoming students to help us measure how much you've learned about spatial information during your time at NC State.

These surveys will in no way affect your grades, and we ask that you please be completely candid in your responses. Results will be reported only for groups — individual responses will be held in confidence. Please do not consult anyone as you complete the survey.

Please write your student ID number here ______________________.

Although we will not identify individual responses, we would like to compare your responses across multiple surveys. **This information is very important to the Department and will help us improve our programs. THANK YOU for your time!!**

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1. Do you know what a geographic information system (GIS) is?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of GIS. (*Skip to Question 4*)
   2. I've heard or read about GIS, but I don't know what it is. (*Skip to Question 4*)
   3. I know what a GIS is and does, but have never used one. (*Skip to Question 4*)
   4. I've used GIS a few times, but don't really know what I'm doing. (*Continue with Question 2*)
   5. I know how to use a GIS. (*Continue with Question 2*)
   6. I consider myself very proficient with GIS. (*Continue with Question 2*)

2. During your time at NC State, how frequently have you used geographic information systems (GIS) in each of the following contexts?
   For each, please circle the most frequent category that applies.

	Never	1 - 2 times	3 - 4 times	5 - 6 times	More than 6 times
a. Job or internship	1	2	3	4	5

b. Course or workshop	1	2	3	4	5
c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

3. Overall, how did you like working with GIS?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

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4. Do you know what a global positioning system (GPS) is?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of GPS. (*Skip to Question 7*)
   2. I've heard or read about GPS, but I don't know what it is. (*Skip to Question 7*)
   3. I know what a GPS is and does, but have never used one. (*Skip to Question 7*)
   4. I've used GPS a few times, but don't really know what I'm doing. (*Continue with Question 5*)
   5. I know how to use a GPS. (*Continue with Question 5*)
   6. I consider myself very proficient with GPS. (*Continue with Question 5*)

5. During your time at NC State, how frequently have you used global positioning systems (GPS) in each of the following contexts?
   For each, please circle the most frequent category that applies.

	Never	1 - 2 times	3 - 4 times	5 - 6 times	More than 6 times
a. Job or internship	1	2	3	4	5
b. Course or workshop	1	2	3	4	5
c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

6. Overall, how did you like working with GPS?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

---

7. Do you know what aerial photography or satellite imagery are?
   Please circle the number corresponding to the most appropriate response.
   1. I've never even heard of them. (*Skip to Question 10*)
   2. I've heard or read about them, but I don't know what they are. (*Skip to Question 10*)
   3. I know what they are, but have never used them. (*Skip to Question 10*)

4. I've used them a few times, but don't really know what I'm doing. (*Continue with Question 8*)
5. I know how to use aerial photography or satellite imagery. (*Continue with Question 8*)
6. I consider myself very proficient with aerial photography or satellite imagery. (*Continue with Question 8*)

8. During your time at NC State, how frequently have you used aerial photography or satellite imagery in each of the following contexts?
For each, please circle the most frequent category that applies.

	Never	1 - 2 times	3 - 4 times	5 - 6 times	More than 6 times
a. Job or internship	1	2	3	4	5
b. Course or workshop	1	2	3	4	5
c. On your own	1	2	3	4	5
d. Other (specify __________)	1	2	3	4	5

9. Overall, how did you like working with aerial photography or satellite imagery?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

---

10. Please indicate about how often you have used the following types of software / technologies within your course work at NC State.
Please circle the most frequent level that applies.

Software	Never	Less than once a month	About once a month	About once a week	Daily
a. Word processing	1	2	3	4	5
b. Spreadsheet	1	2	3	4	5
c. Electronic mail	1	2	3	4	5
d. World Wide Web	1	2	3	4	5
e. File downloads	1	2	3	4	5
f. Digital photography	1	2	3	4	5

11. Overall, how comfortable are you with computers, software, and technology?

Not at all	Only a little	Somewhat	Comfortable	Very Comfortable
1	2	3	4	5

Finally, **we need to know a few things about you**, **to better understand your responses**.
Please circle the appropriate response for each question.

12. To what extent do you agree with the following statement: "Knowledge about spatial information technologies (GIS, GPS, aerial photography, satellite imagery) is important in forestry, natural resources, fisheries and wildlife, and environmental technology related fields"?

Strongly Disagree	Disagree Somewhat	Don't Know	Agree Somewhat	Strongly Agree	Strongly Disagree
1	2	3	4	5	1

13. Do you expect to use spatial information technologies in your career?

Not at all	Only a little	Somewhat	A good deal	A lot
1	2	3	4	5

14. Your sex.

    1. Male
    2. Female

15. Your year.

    1. Freshman
    2. Sophomore
    3. Junior
    4. Senior
    5. Graduate Student
    6. Other

16. Your age.

    1. 21 or younger
    2. 22
    3. 23
    4. 24
    5. 25
    6. 26 or older

17. Did you transfer into a Department of Forestry & Environmental Resources program?

1. No
2. Yes, from within NC State
3. Yes, from another school

18. What curriculum are you in?

    1. Forest Management
    2. Natural Resources Ecosystem Assessment
    3. Natural Resources Policy and Administration
    4. Environmental Science: Watershed Hydrology
    5. Fisheries, Wildlife, and Conservation Biology
    6. Environmental Technology and Management
    7. Graduate Student
    8. Other

19. When do you plan to graduate (or complete your undergraduate course work)?

    1. May 20xx
    2. August 20xx (complete courses)
    3. December 20xx
    4. 20xx
    5. Other

Thank you for completing this survey.

Appendix G. Cross Tabulations and McNemar's Tests

Practice of Environmental Technology, spring 2010.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	30	10	7	0	13	0.002*	57%
List three types of vector data	30	9	6	0	15	0.004*	50%
List two examples of raster data	30	5	1	0	24	0.063	20%
Discuss the relationship between scale and resolution	30	8	0	4	18	0.388	27%
Compare two GPS data collection methods	30	9	3	0	18	0.004*	40%
Describe an application of the buffer and clip tools	30	6	1	1	22	0.125	23%
List five essential map elements	30	9	13	1	7	0.021*	73%

*Pretest and posttest responses were significantly different at the 95% confidence level ($\alpha = 0.05$).

Practice of Environmental Technology, **spring 2011**.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	22	4	9	3	6	1.000	59%
List three types of vector data	22	9	9	0	4	0.004*	82%†
List two examples of raster data	22	3	11	0	8	0.250	64%
Discuss the relationship between scale and resolution	22	3	6	2	11	1.000	41%
Compare two GPS data collection methods	22	7	3	1	11	0.070	45%
Describe an application of the buffer and clip tools	22	7	6	0	9	0.016*	59%
List five essential map elements	22	3	15	2	2	1.000	82%†

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

†The number of correct posttest responses divided by the total number of posttest respondents was greater than the faculty's 80% performance target.

Forest System Mapping & Mensuration II, **summer 2009**.

Question	**Number of pre-post matches**	**Incorrect before, correct after**	**Correct before and after**	**Correct before, incorrect after**	**Incorrect before and after**	**McNemar's test *p*-value**	**Overall performance**
List three data sources	24	2	2	1	19	1.000	17%
List three types of vector data	24	6	2	0	16	0.031*	33%
List two examples of raster data	24	9	1	0	14	0.004*	42%
Discuss the relationship between scale and resolution	24	5	8	5	6	1.000	54%
Compare two GPS data collection methods	24	7	0	0	17	0.016*	29%
Describe an application of the buffer and clip tools	24	8	3	0	13	0.008*	46%
List five essential map elements	24	10	5	1	8	0.12*	63%

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

Forest System Mapping & Mensuration II, summer 2010.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	15	1	3	0	11	1.000	27%
List three types of vector data	15	6	1	0	8	0.031*	47%
List two examples of raster data	15	2	2	0	11	0.500	27%
Discuss the relationship between scale and resolution	15	4	2	2	7	0.687	40%
Compare two GPS data collection methods	15	3	0	0	12	0.250	20%
Describe an application of the buffer and clip tools	15	7	1	1	6	0.070	53%
List five essential map elements	15	2	7	1	5	1.000	60%

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

Forest Management, fall 2008.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	12	3	6	0	3	0.250	75%
List three types of vector data	12	3	4	1	4	0.625	58%
List two examples of raster data	12	3	2	0	7	0.250	42%
Discuss the relationship between scale and resolution	12	1	5	1	5	1.000	50%
Compare two GPS data collection methods	12	2	0	0	10	0.500	17%
Describe an application of the buffer and clip tools	12	3	6	0	3	0.250	75%
List five essential map elements	12	4	4	1	3	0.375	67%

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

Forest Management, fall 2009.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	12	1	5	1	5	1.000	50%
List three types of vector data	12	3	4	0	5	0.250	58%
List two examples of raster data	12	5	2	0	5	0.063	58%
Discuss the relationship between scale and resolution	12	2	3	2	5	1.000	42%
Compare two GPS data collection methods	12	3	1	1	7	0.625	33%
Describe an application of the buffer and clip tools	12	5	6	0	1	0.063	92%[†]
List five essential map elements	12	4	5	0	3	0.125	75%

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

[†]The number of correct posttest responses divided by the total number of posttest responses was greater than the faculty's 80% performance target.

Forest Management, fall 2010.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	18	4	4	3	7	1.000	44%
List three types of vector data	18	7	7	1	3	0.070	78%
List two examples of raster data	18	2	1	3	12	1.000	17%
Discuss the relationship between scale and resolution	18	4	3	2	9	0.687	39%
Compare two GPS data collection methods	18	3	1	1	13	0.625	22%
Describe an application of the buffer and clip tools	18	8	9	1	0	0.039*	94%†
List five essential map elements	18	2	13	0	3	0.500	83%†

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

†The number of correct posttest responses divided by the total number of posttest responses was greater than the faculty's 80% performance target.

Wildlife Ecology & Management, summer 2010.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	33	1	4	4	24	0.357	15%
List three types of vector data	33	19	5	0	9	< 0.001*	73%
List two examples of raster data	33	4	1	1	27	0.357	15%
Discuss the relationship between scale and resolution	33	10	8	3	12	0.092	55%
Compare two GPS data collection methods	33	3	2	0	28	0.250	15%
Describe an application of the buffer and clip tools	33	16	8	0	9	< 0.001*	73%
List five essential map elements	33	23	5	0	5	< 0.001*	85%†

*Pretest and posttest responses were significantly different at the 95% confidence level (α = 0.05).

†The number of correct posttest responses divided by the total number of posttest responses was greater than the faculty's 80% performance target.

Natural Resource Measurements, **spring 2011**.

Question	Number of pre-post matches	Incorrect before, correct after	Correct before and after	Correct before, incorrect after	Incorrect before and after	McNemar's test *p*-value	Overall performance
List three data sources	27	6	7	2	12	0.289	48%
List three types of vector data	27	9	3	0	15	0.004*	44%
List two examples of raster data	27	0	1	0	26	1.000	4%
Discuss the relationship between scale and resolution	27	7	2	1	17	0.070	33%
Compare two GPS data collection methods	27	6	0	0	21	0.031*	22%
Describe an application of the buffer and clip tools	27	2	3	1	21	1.000	19%
List five essential map elements	27	12	10	1	4	0.003*	81%[†]

*Pretest and posttest responses were significantly different at the 95% confidence level ($\alpha = 0.05$).

[†]The number of correct posttest responses divided by the total number of posttest responses was greater than the faculty's 80% performance target.

Appendix H. Overall Posttest Performance by Course and Question

Course, year	***n***	**Data sources**	**Vector data**	**Raster data**	**Scale and resolution**	**GPS data collection**	**Spatial analysis**	**Map elements**	**Overall average by course**
Practice of Environmental Technology, seniors, 2010	30	57%	50%	20%	27%	40%	23%	73%	41%
Practice of Environmental Technology, seniors, 2011	22	59%	82%*	64%	41%	45%	59%	82%*	62%
Forest System Mapping & Mensuration II, rising juniors, 2009	24	17%	33%	42%	54%	29%	46%	63%	41%
Forest System Mapping & Mensuration II, rising juniors, 2010	15	27%	47%	27%	40%	20%	53%	60%	39%
Forest Management, seniors, 2008	12	75%	58%	42%	50%	17%	75%	67%	55%
Forest Management, seniors, 2009	12	50%	58%	58%	42%	33%	92%*	75%	58%
Forest Management, seniors, 2010	18	44%	78%	17%	39%	22%	94%*	83%*	54%
Wildlife Ecology & Management, rising seniors, 2010	33	15%	73%	15%	55%	15%	73%	85%*	47%
Natural Resource Measurements, juniors, 2010	23	83%*	57%	30%	48%	52%	52%	57%	54%
Natural Resource Measurements, juniors, 2011	27	48%	44%	4%	33%	22%	19%	81%*	36%
Overall average by Question	216	48%	58%	32%	43%	30%	59%	73%	

*Eight of 70 questions met the faculty's 80% performance target.

Appendix I. Semester-to-Semester Comparison of Overall Pretest, Posttest, and Gain Scores

			Mean ranks		
Course	**Year**	***n***	**Pretest**	**Posttest**	**Gain scores**
Practice of Environmental Technology	2010	30	20.87	22.33	27.57
	2011	22	34.18	32.18	25.05
			$p = 0.001$*	$p = 0.019$*	$p = 0.545$
Forest System Mapping & Mensuration II	2009	24	20.17	20.17	21.17
	2010	15	19.73	19.73	18.13
			$p = 0.903$	$p = 0.907$	$p = 0.408$
Forest Management	2008	12	12.42	11.88	11.75
	2009	12	12.58	13.13	13.25
			$p = 0.952$	$p = 0.657$	$p = 0.595$
Forest Management	2009	12	14.83	16.75	16.79
	2010	18	15.94	14.67	14.64
			$p = 0.731$	$p = 0.517$	$p = 0.505$
Natural Resource Measurements	2010	23	26.15	29.85	29.46
	2011	27	24.94	21.80	22.13
			$p = 0.761$	$p = 0.047$*	$p = 0.068$

*Overall pretest, posttest, or gain score mean ranks were significantly different at the 95% confidence level ($\alpha = 0.05$).

Appendix J. Course-to-Course Comparison of Overall Pretest, Posttest, and Gain Scores

				Mean ranks	
Comparison group	**Class**	***n***	**Pretest**	**Posttest**	**Gain scores**
Forest Management (2010)	Senior	18	31.97	28.83	22.17
vs. Practice of Environmental Technology (2010)	Senior	30	20.02	21.90	25.90
			p = 0.003*	p = 0.092	p = 0.363
Forest Management (2010)	Senior	18	19.61	17.89	19.83
vs. Practice of Environmental Technology (2011)	Senior	22	21.23	22.64	21.05
			p = 0.659	p = 0.195	p = 0.739
Natural Resource Measurements (2010)	Junior	23	30.63	30.87	29.91
vs. Wildlife Ecology & Management (2010)	Rising Senior	33	27.02	26.85	27.52
			p = 0.388	p = 0.358	p = 0.583
Natural Resource Measurements (2011)	Junior	27	32.02	25.54	25.50
vs. Wildlife Ecology & Management (2010)	Rising Senior	33	29.26	34.56	34.59
			p = 0.518	p = 0.043*	p = 0.038*

*Overall pretest, posttest, or gain score mean ranks were significantly different at the 95% confidence level (α = 0.05).

Appendix K. Curricula-to-Curricula Comparison of Outgoing Non-Matching Knowledge Surveys

		Mean Ranks		
Curricula	***n***	**GIS**	**GPS**	**Imagery**
Forest Management vs.	148	100.67	100.52	97.23
Natural Resources	44	82.47 $p = 0.032$*	82.98 $p = 0.035$*	94.06 $p = 0.681$
Forest Management vs.	148	92.31	87.83	92.07
Fisheries, Wildlife, & Conservation Biology	25	55.56 $p < 0.001$*	82.08 $p = 0.538$	56.96 $p < 0.001$*
Forest Management vs.	148	93.21	90.54	96.85
Environmental Technology & Management	38	94.64 $p = 0.861$	105.03 $p = 0.086$	80.46 $p = 0.046$*
Natural Resources vs.	44	37.91	33.55	39.38
Fisheries, Wildlife, & Conservation Biology	25	29.88 $p = 0.087$	37.56 $p = 0.376$	27.30 $p = 0.008$*
Natural Resources vs.	44	37.35	35.53	43.68
Environmental Technology & Management	38	46.30 $p = 0.059$	48.41 $p = 0.007$*	38.97 $p = 0.328$
Fisheries, Wildlife, & Conservation Biology vs.	25	23.28	28.00	27.40
Environmental Technology & Management	38	37.74 $p < 0.001$*	34.63 $p = 0.115$	35.03 $p = 0.085$

*Outgoing GIS, GPS, or imagery mean ranks were significantly different at the 95% confidence level ($\alpha = 0.05$).

Appendix L. Assessment Planner

Assessment Planner for Geospatial Student Learning Outcomes
Department of Forestry & Environmental Resources
North Carolina State University

I. Statement of Purpose

Geospatial tools and technologies are core competencies for natural resource professionals due to the monitoring, modeling, and mapping capabilities they provide. To prepare students with needed background, geospatial instructional activities have been integrated across Forest Management; Natural Resources; Fisheries, Wildlife, & Conservation Biology; and Environmental Technology & Management curricula in the Department of Forestry and Environmental Resources at North Carolina State University. The effectiveness of the integration and how well students are meeting geospatial outcomes are as of yet unknown. The purpose of this guide is to aid facilitators in the planning and assessment of geospatial student learning outcomes.

II. Student Learning Outcomes

Content analysis of structured interview data show that faculty and administrators viewpoints on the purpose of integration generally fell into two categories. Some believe integration should expose students to geospatial technologies, making them aware of the types of analyses they can bring to bear on resource management issues. Others believe students should acquire geospatial skills and abilities and be able to perform routine spatial analysis tasks. The content analysis resulted in the identification of five objective categories and a number of recurring student learning outcomes (Table 1). Participants routinely described skills-based, information literacy, conceptual knowledge, and metacognitive outcomes. Faculty desire that these outcomes be met at the application and analysis levels in taxonomies of educational objectives. Participants also expect affective outcomes and desire students to accept, value, and internalize spatial analysis as part of becoming natural resource professionals. Participants' responses were also used to identify an initial performance target (80% satisfactory) for the assessments.

III. **Assessing Outcomes -** The following outcomes will be assessed using the instrumentation indicated (Table 2):

1. Students' exposure to the technologies over the course of their programs.

- Longitudinal knowledge surveys developed by Drs. Hess and Cheshire in 2002, an indirect assessment method, are used to assess students' awareness of and confidence in their ability to use geospatial technologies. The data are analyzed visually through graphs, with descriptive statistics such as median and mode, and tested with signed-rank and rank-sum tests. Detailed analysis methods are presented in Chapter 4.
    - The incoming survey (Appendix E) is administered to all NR 100 students each fall semester before they receive any geospatial instruction.
    - The outgoing survey (Appendix F) is administered to ET 460, FOR 406, FW 411, NR 400 students in April each spring semester. Facilitators should schedule the April assessment with faculty in March to avoid last minute scheduling issues.

2. Students' skills-based, information literacy, and conceptual knowledge outcomes are assessed using recurring tracking questions, pre-post tests, and evaluation of students' deliverables with rubrics.

- Tracking questions are used to track students' factual, conceptual, and procedural knowledge in both NR 100 (each fall semester) and ET 460 (each spring semester). For these assessments, the number of satisfactory responses divided by the number of responses (percent satisfactory) is calculated and tracked. Criteria for satisfactory responses generally follow faculty's grading criteria.

- NR 100 (each fall semester) tracking questions are administered on either the midterm or final exam.

  - 2010 questions:

    18. To what does the acronym GPS refer?
    19. To what does the acronym GIS refer?
    24. How can GPS contribute to a GIS for a research project?
    25. In the context of GIS, why are overlays useful as an analytical technique?

  - 2011 questions:

    15. To what does the acronym GPS refer?
    16. To what does the acronym GIS refer?
    17. Why should you save your work frequently while creating a GIS thematic map?
    18. Which of the 4 things we said students would learn in NR 100 relates to the fact that most assignments included a map?

- ET 460 (each spring semester) tracking questions are nested inside the pre-post test assessment (Appendix C).

  - 2010 questions:

    11. Discuss two ways GIS can be used to aid in the design and implementation of an environmental assessment.
    12. Discuss two ways GPS can be used to aid in the design and implementation of an environmental assessment.

- 2011 questions:

  11. Discuss two ways GIS can be used to aid in the design and implementation of an environmental assessment.

  12. Discuss two ways GPS can be used to aid in the design and implementation of an environmental assessment.

- Students' deliverables from FOR 172 and FOR 405 are evaluated with rubrics each fall semester.

  - FOR 172 students' maps are assessed for map making outcomes using a variation of the FOR 172 rubric (Table 3). Point values and what constitutes a satisfactory submission varies somewhat year to year, based on the judgment of the teaching assistants that year.

  - FOR 405 students' lab reports from the surface interpolation lab are assessed using the FOR 405 rubric (Table 4). A rubric score of ten or greater is required to satisfactorily meet the desired performance standard for this assessment.

- Term projects from NR 300 and NR 484 are collected each spring semester and are evaluated using Anderson and Krathwohl's (2001) taxonomy as a holistic rubric (Table 5). Satisfactory reports demonstrate that an understanding of factual and conceptual knowledge, the application of procedural knowledge, and methods and findings are appropriately and effectively integrated and communicated in the report.

- Capstone management plans from NR 400 and FOR 406 are collected each spring semester and are evaluated using Anderson and Krathwohl's (2001) taxonomy as a holistic rubric (Table 5). Satisfactory reports demonstrate that an understanding of factual and conceptual knowledge, the application of procedural knowledge, and methods and findings are appropriately and effectively integrated and communicated in the report.

- Pre-post tests are used to assess skills-based, information literacy, and conceptual knowledge outcomes in FOR 273, NR 300, FW 311, FOR 405, ET 460 before and after course-embedded activities. The pretest should be administered before any geospatial instruction. The posttest should be administered several weeks (accept for FOR 273 and FW 311 summer camps) after the instruction. Data are analyzed using crosstabs, McNemar's test, summary statistics, and curricula and courses are compared with rank-sum tests. Detailed analysis methods are presented in Chapter 4.

IV. Using Anderson and Krathwohl's Taxonomy as a Rubric

This section provides a brief explanation of how Anderson and Krathwohl's taxonomy (Table 5) can be used as a generic evaluative rubric to assess a variety of students' deliverables.

For example, a natural resources course project required students to plan and carry out an environmental assessment using appropriate geospatial methods. The first step in evaluating project reports is to read them looking for evidence of geospatial methods used in project planning, analysis, and reporting. The following are excerpts from such a report.

1. "…We used ArcGIS 9.3.1 to create a map for field use. We first started by downloading the necessary shape files that represent the [redacted] Tract boundary, the major roads around the property and the streams that run through the property…"

2. "…We used ArcGIS to find the exact area of the [redacted] Tract (38.27 acres). We determined it was necessary to sample approximately 10% of 38.27 acres (37 1/10th acre plots) in order to obtain accurate predictions from our data…"

3. "…After we used ArcGIS to create a map of systematic sampling within the [redacted] Tract, we went through the process of locating and marking those points. First we loaded the locations of the points we generated from the computer into a Global Positioning System…"

4. "…We then used the GPS in the field to navigate to the points and marked them with flags and flagging tape…"

5. "…After all sampling points had been mapped with GPS, the data was uploaded and corrected in Pathfinder Office. The shape files were exported from Pathfinder Office and added to our ArcMap Layout…"

6. "…Sampling points lined up with Stream map and were denoted as Green Circles on maps. All Sampling data was added to an excel file and into the attributes table for the points in ArcMap…"

When examples of desired learning are observed in students' reports, they are summarized. For example, the six excerpts above could be summarized in the following way.

1. make map, download data

2. calculate area, recognize need for samples

3. generate sample plots, link GIS to GPS

4. use navigation, link GPS to field work

5. perform correction, link GPS to GIS

6. display data, attribute data

Next, the taxonomy table can be used to classify each summary based on the knowledge types involved and cognitive processes associated with the action words describing the behavior.

1. make map – apply procedural knowledge
   download data – understand conceptual knowledge, apply procedural knowledge

2. calculate area – apply procedural knowledge
   recognize need for samples – understand conceptual knowledge

3. generate sample plots – understand conceptual knowledge, apply procedural knowledge
   link GIS to GPS – evaluate procedural knowledge, apply conceptual knowledge

4. use navigation – apply procedural knowledge
   link GPS to field work – evaluate procedural knowledge, apply conceptual knowledge

5. perform correction – understand conceptual knowledge, apply procedural knowledge
   link GPS to GIS – evaluate procedural knowledge, apply conceptual knowledge

6. display data – understand conceptual knowledge, apply procedural knowledge
   attribute data – understand conceptual knowledge, apply procedural knowledge

Next, the classifications can be tallied in a blank taxonomy table to visualize students' performance by knowledge types and cognitive processes (Table 6). Actual performance can then be compared to desired performance and the evaluator can make a judgment regarding how well intended outcomes were met.

V. Tables and Rubrics

Table 1. Geospatial student learning outcomes.

Overall objective categories	**Times mentioned**	**Desired learning behavior**	**Recurring student learning outcomes** Students should possess the ability to:
Skills-Based	98	Apply and Analyze	• read, make, and communicate with maps • perform routine spatial analysis tasks • perform rudimentary spatial statistics • plan and execute a GPS field data collection mission
Factual Knowledge & Information Literacy	21	Remember, Understand, and Apply	• define and use terminology correctly • recall specific details related to the discipline • identify reliable information sources • download and organize information
Conceptual Knowledge	24	Understand and Apply	• recognize spatial problems and propose possible solutions • recognize what data and analysis techniques are needed • explain how the tools can be used together to solve problems • link the tools, fieldwork, analysis and reporting
Self-Awareness & Problem Solving (Metacognitive)	12	Understand and Apply	• recognize their own levels of understanding • identify strategies to seek help • devise strategies to solve problems
Feelings & Values (Affective)	27	Value and Characterize (Adopt and Internalize)	• willingly include geospatial approaches in their methodologies and reporting • identify use of the tools and technologies as part of becoming a resource management professional

Table 2. Summary of when assessments occur for each participating course and the instrumentation to be used.

Course number	**Tracking questions**	**Classwork rubrics**	**Term projects**	**Capstone management plans**	**Pre-post tests**	**Longitudinal knowledge surveys**
NR 100	Each fall semester					Each fall semester
FOR 172		Each fall semester				
FOR 273	Each summer semester				Each summer semester	
NR 300			Each spring semester		Each spring semester	
FW 311					Each summer semester	
NR 400				Each spring semester		Each spring semester
FOR 405		Each fall semester			Each fall semester	
FOR 406				Each spring semester		Each spring semester
FW 411						Each spring semester
ET 460	Each spring semester				Each spring semester	Each spring semester
NR 484			Each fall semester			

Table 3. FOR 172 learning objectives and grading rubric.

Learning Objectives
Gain experience in using high end GPS units and their software
Gain experience downloading GPS data
Practice using ArcGIS software to become familiar with the software and its capabilities
Learn the essentials of putting together a map

Grading Rubric	**Points**
The map itself with 4 layers (themes)	1
Stands displayed by type (color ramp)	1
Legend	1
Title	1
Scale bar (appropriate to data i.e., feet, meters, chains, etc.)	1
North arrow	1
Name of creator	1
Date of creation	1
Appearance and level of effort	2

Table 4. Rubric used to generate assessment data from FOR 405 spatial analysis lab reports.

Student performance (**16 points possible)**	**Weak 0 points**	**Good 1 point**	**Very good 3 points**	**Excellent 4 points**
Surface interpolation	response does not indicate why sample locations were or were not included in the analysis	response does indicate an understanding of how sample-points are being used	tradeoffs are addressed by example using data e.g., discussion of "continuous" elevation data	argues that landscape features provide ecosystem services that are dynamic and often follow a continuous data model i.e., no hard boundary
Averaging by stand	response does not indicate why sample locations were or were not included in the analysis	response does indicate an understanding of how sample-points are being used	tradeoffs are addressed by example using data e.g., discussion of "discrete" GPS positions	argues that discrete management units are necessary in order to implement recommendations so boundaries must be delineated somewhere
Overall feature symbolization and cartographic representation	poor color selection; data not classified in a thoughtful way; missing map elements; improper legend names	data classified thoughtfully; no missing map elements; no improper names in the legend	pattern and color selections mimic characteristics of the features they represent; map is well organized	transparency used to depict spatial interaction among features; a truly 'polished' map
Intended use and audience appropriateness of maps	map is not appropriate for intended use e.g., unusable scale on field map; the audience is not actively targeted e.g., use of jargon on maps intended for laypersons	map is appropriate for intended use; audience is actively targeted; purpose of map is not readily apparent	purpose of map is somewhat apparent; map requires some explanation by author	purpose of map is apparent; map requires no explanation by author

Table 5. Anderson and Krathwohl's taxonomy for learning, teaching, and assessing. (Source: adapted from Anderson and Krathwohl 2001)

	The cognitive process dimension					
The knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	list	summarize	organize	classify	rank	combine
Conceptual Knowledge	describe	explain	demonstrate	differentiate	critique	propose
Procedural Knowledge	recall	generalize	utilize	distinguish	justify	develop
Metacognitive Knowledge	recognize	interpret	implement	organize	check	plan

The italicized words inside the matrix are example key action verbs for stating desired learning outcomes.

Table 6. Example Natural Resources Course Project Assessment Matrix. (Source: adapted from Anderson and Krathwohl 2001)

	The cognitive process dimension					
The knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		𝍸𝍷	𝍷𝍷𝍷			
Procedural Knowledge			𝍸𝍷𝍷𝍷		𝍷𝍷𝍷	
Metacognitive Knowledge						