A Creative Way to Teach and Learn Advanced Technical Concepts in Geographic Information Systems

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Abstract

This paper presents a creative *case-based modern-style pedagogical* approach for teaching and learning advanced technical concepts in geographic information systems (GIS) using classroom observations covering an eight-year study period, 2004-2011. Assessment data was collected and analyzed to provide useful insights about this approach. Included in this paper are results of specific case studies that were analyzed using a sample of students between 2004 and 2006. The assessment data and respondents consistently indicated that a case study approach offered them an excellent and enabling environment to learn advanced technical concepts. These findings support the *use of a case-based modern-style pedagogical method* because it does not only promote a student's desire to learn and discover new concepts, but also allows them to be actively involved in finding real world GIS solutions. The teaching method encourages, engages, and provokes students to think critically of the technical subject matter. Besides, the method creates an interesting learning experience, simulates learning, and promotes interactive dialogue between the instructor and the students. Findings in this study have implications on the learning process and the adoption of this creative approach could help provide a meaningful learning experience for educators involved in teaching advanced technical concepts.

Keywords: GIS education, Pedagogical approaches, Technology education, Active learning, GIS instructional strategies, Geography education

1. Introduction

Teaching geographic information systems (GIS) courses can be challenging because of its breadth and interdisciplinary nature (Wikle, 1998; Doering, 2004; Baker and White, 2003; Kerski, 2003; Johansson and Pellikka, 2005; Favier and Van Der Schee, 2012). Both the teacher and student must cope with constant changes particularly new software applications and emerging areas of interest. Learning outcomes should be aligned to reflect any rapid technical changes so as to provide students with relevant GIS knowledge and job market skills. This dynamic situation creates a serious demand upon curriculum and instructional strategies, thus there is a consistent need to adjust learning goals and objectives to fit new challenges, which can at times, can be overwhelming for new GIS instructors.

As a way of resolving some of these challenges, this paper proposes a more creative way to teach advanced GIS based on observations collected over an eight-year study period. As a GIS instructor, I first thought about this teaching idea in May 2000 following my participation in *Case Studies in a Science Teaching Workshop* organized by the University at Buffalo's National Center for Case Study Teaching in Science, with support from the National Science Foundation. Participants involved in this workshop were supposedly the "guinea pigs" for a case studies teaching project. Professor Clyde F. Herreid, the Principal Investigator (PI) tested his case studies on workshop participants. During the workshop three important aspects on the use of case-based approaches were taught: (1) how to develop and write cases; (2) how to teach with case studies; and (3) how to assess learning outcomes with cases (Herreid, 1994).

Following this workshop I was inspired to think about my own teaching and how I could use the experience to improve the teaching of advanced GIS concepts. I realized the significance of using learning approaches which emphasize a collaborative case-based approach (Wheatley, 1986; Boehrer and Linsky, 1990; Williams, 1992; Barnes et al., 1994; Herreid, 1994; Lantz and Walczak, 1997).

1.1 Conceptual framework

The Geography program at Southern Illinois University Carbondale (SIUC) offers a range of GIS and Remote Sensing Courses; in which GIS is one of three concentrations for both undergraduate and graduate students. We have witnessed an increase in enrollment and strong interest among students since 2003 after a major overhaul of the curriculum design. Our GIS program follows the proposed GIS pedagogical approaches (CTGV, 1990; CTGV, 1992; Baker, 1999; Carolin, 1999; Kirschner and Davis, 2003; Doering, 2004; Mishra and Koehler, 2006; Favier and Van Der Schee, 2012) and employs a mixture of three instructional models: Basics First, Immediate Feedback Direct Instruction; Structured Problem Solving; and The Guided Generation Model (CTGV, 1990; CTGV, 1992). We promote anchored instruction (Savery and Duffy, 1996; Doering, 2004) through the use of lecture and laboratory-based active learning experiences with a key goal of strengthening apprenticeship training among our students. We train GIS students to become independent critical thinkers and learners rather than simply being able to perform basic computational tasks or retrieve basic knowledge. Our central mission is to help develop the core ability of our students so that they can identify and define issues and problems on their own rather than simply responding to problems that others have posed (Doering, 2004). This is consistent with the CTGV learning and instructional goals (CTGV, 1990; CTGV, 1992; Favier and Van Der Schee, 2012) and we try to cultivate a sustained interest and motivation among our GIS students through the process of active learning (Savery and Duffy, 1996; Favier and Van Der Schee, 2012).

The design of a collaborative case study to teach and learn advanced technical concepts is informed by two instructional models: the Structured Problem Solving and the Guided Generation Model. The former focuses on the importance of learners making errors and struggling with a task and the latter emphasizes the role of the teacher in the learning process to support inquiry-based geography education (Favier and Van Der Schee, 2012), in this model, the teacher serves as a facilitator and student peers engage in cooperative learning (Savery and Duffy, 1996; Favier and Van Der Schee, 2012). The assumption for the success of this model is premised on the view that learners taking Advanced GIS Studies have already been exposed to the first instructional model of Basics First, Immediate Feedback Direction Instruction through the introductory level course of GIS.

The way learning occurs among individuals still fascinates many prominent educators (Chickering and Gamson, 1991; Carolin, 1999; Summerby-Murray, 2001; Jennings and Huber, 2003; Drennon, 2005), but a detailed book edited by Wilson provides some guidance on this very important matter (Wilson, 1996). In one of the chapters, Savery and Duffy (1996) have explored at length the theory of constructivist learning environment, which they have conceived following three primary propositions:

1) That understanding is in our interactions with the environment
2) That cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned
3) That knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings.

The three propositions can be reinforced by eight core instructional principles (Savery and Duffy, 1996): (1) anchor all learning activities to a larger task or problem; (2) support the learner in developing ownership for the overall problem/task; (3) design an authentic task; (4) design the task and learning environment to reflect the complexity of the environment so as to enhance functional aspects of the learning process; (5) give the learner ownership of the process used to develop a solution; (6) design the learning environment to support and challenge the learner's critical thinking; (7) encourage the testing of ideas against alternative views and alternative contexts; and (8) provide opportunity for and support reflection on both the content learned and the learning process. Such nuggets fuel a variety of learning environments, thus enabling a strong atmosphere of active learning, inquiry-based or problem-based learning. Problem-based learning strategies require some form of team-based collaborative environment that is similar to a case-based approach (Williams, 1992). The suggested teaching principles, including the CTGV are consistent and are inspired by constructivism (Summerby-Murray, 2001; Drennon, 2005). Whereas different language is used to describe Chickering and Gamson's seven principles for good practice in undergraduate education, the motivation for the teaching principles is the same. Adopting nuggets of constructivist teaching principles fosters strong collaborative learning environments enabling the growth of effective teaching practices, which can be used to set high academic expectations and close student performance gaps. This conceptual framework is the basis for the proposed *case-based modern-style pedagogical approach* (Figure 1). The use of this approach aims at maximizing the benefits of learning advanced technical concepts.

1.2 Course syllabus

Geog 420 "Advanced GIS Studies" is an upper-level undergraduate, to graduate-level course that focuses on six fundamental areas of geographic information science (1) geospatial ontologies; (2) enterprise and cloud computing frameworks for web GIS services; (3) GIS application design; (4) spatial data mining and knowledge discovery; (5) data structure and algorithms; and (6) visual analytics and 3-D representation. This course provides in-depth technical knowledge and skills to enable students to author, serve, and use geospatial data in a more creative and innovative way than simply clicking the mouse. The learning approach here is to use small study group discussions and presentations to support an inquiry-based GIS education. The whole class is organized into four groups based on three criteria (1) prior knowledge and critical skills, (2) passion and demonstrated potential for specific technical areas, and (3) student’s interest in fundamental areas: GIS programming, cognitive science, database design and systems, computational geometry, analytical, conceptual, and mathematical competency.

The course offers nine lab studios covering essential areas of visual analytics and 3-D representation, and application design. The motivation for this is to provide critical computational skills and promote active learning experiences in GIS application design accomplished by using advanced computing software. Students work in a collaborative team to design and implement an inquiry-based GIS project solving a major real world problem.

The course has four specific learning outcomes. The course seeks to (1) Provide a deep understanding of GIScience (theoretical foundations) that informs GIS technology—the nuts and bolts of the science that advance GIS technology, “what you must known to succeed in a GIS career;” (2) Expose students to a wide range of GIS design and database concepts; (3) Expose students to complex GIS data structures, models, and algorithms; and (4) Provide hands-on GIS experiences and skills training using well-designed studio exercises.

1.3 A case study teaching model

The case-based approaches were originally developed from Harvard University. A case-based approach utilizes real world examples or stories to illustrate and teach abstract concepts in science and promotes active learning experiences among students. Strong empirical data suggests that when learners use case-based approaches they learn and understand abstract concepts. It also increases students' desire to learn and discover new concepts (Boehrer and Linsky, 1990; Williams, 1992; Barnes et al., 1994; Herreid, 1994). The approach supposedly encourages, engages, and provokes student’s critical thinking.

Using this approach, the instructor leads in the development of cases in two areas (1) visual analytics and 3-D representation, and (2) GIS application design, while the students develop cases in four areas. The instructor and the students have direct ownership of the cases they have developed.

The class is divided into four collaborative learning groups. Each group undertakes to research and present their case study. The learning groups include (1) Enterprise and cloud computing frameworks—ERP Learning Group; (2) Data Structure, Algorithms, and Spatial Data Mining—GDF Learning Group; (3) GIS Programming—G-Code Learning Group; and (4) Cognitive Science/Geospatial Ontologies—Concept-GIS Learning Group.

Each group (referred in the last paragraph as a learning group) is provided with a summary of learning goals, list of topics to be investigated, and a list of learning expectations. The instructor also provides each group with relevant/supporting instructional materials, research articles, and references to use in developing their cases; and before each oral presentation, the instructor reviews the material to be presented and offers written feedback and suggestions. Upon receiving a revised presentation, the instructor posts a PDF copy on the course website 48 hours in advance for the rest of the students to review the same material and prepare them for the critical discussions. After the oral presentations, students are again encouraged to revise their cases using all of comments and suggestions given.

In total, each group presents four separate oral presentations for one hour under the following sub-headings: overview of principles and concepts, principles and concepts I and II, and the final case study or demonstration of GIS application. The first three presentations deal with core concepts while the last one focuses on the final project relative to the Department of Homeland Security. In each presentation, the instructor observes the presentations, facilitates the discussion, and makes a short report (using a grading rubric) regarding critical thinking, management of questions, level of computational skills, effective use of multimedia, originality and excellence, and group dynamics. The students also keep a log report, which contains details on self-evaluation, peer evaluation, and a summary of raw data regarding individual participation, attendance, contributions, and assigned roles. At the end of the semester they are required to submit a complete GIS portfolio with the oral presentations, log report, an application, and a 20-page paper.

The overarching objective in pursuing the cases is to complete a comprehensive GIS design project for Homeland Security. The application focuses on developing a GIS for Homeland Security (HLS) entitled "Tools for the Future: A GIS for HLS". Two examples of the cases are given in Appendix 1. The design class assumes that enrolled students have a strong familiarity with matters of homeland security in part because of 9/11 events.

Sample examples of the application design projects include: (1) defining geospatial ontologies for managing HLS (Concept-GIS Learning Group); (2) developing geospatial data models for HLS (GDF Learning Group); (3) a GIS programming application for managing HLS; must be coded as a standalone or a web-based GIS program (G-Code Learning Group); and (4) frameworks for creating an enterprise-wide and could computing GIS system for HLS (ERP Learning Group).

1.4 Motivation and justification

The motivating factor behind the GIS application design task is related to the desire to build a GIS system for HLS. HLS is an important national security issue and has wide implications in our everyday lives. Besides the recent 9/11 terrorist events, there is renewed urgency to build smart tools to help with the war on terrorism. The overall task provides students with a unique opportunity to not only reflect on current extreme events, but also to relate these events to GIS so as to design effective responses and mitigation control measures. The knowledge acquired from designing the GIS application and assembling a GIS portfolio provides a solid basis for learning advanced technical concepts in GIS. As students grapple with issues related to keeping the Homeland safe, they are made to apply advanced GIS concepts to design feasible solutions. The learning experiences make classroom sessions interesting and culminate into the development of practical solutions.

1.5 Specific aims

This study has three specific aims:

1). To evaluate student's knowledge on advanced GIS concepts before and after taking the GIS course

2). To evaluate students mental development and critical computational skills after learning new advanced technical concepts

3). To share learning and teaching experiences gained from the use of a creative *case-based modern-style pedagogical* approach

2. Materials and Methods

2.1 Study design

The study design comprised three evaluation instruments: (1) classroom observations, (2) content knowledge survey, and (3) oral and written interview protocols. Classroom observations were conducted during an eight-year period and recorded by using a set of standard assessment questions and grading rubrics. Content knowledge survey was conducted on a sample of forty students/subjects (n = 40) from three academic years between 2004 and 2006. All students who took advanced GIS during this three-year study period were requested to participate in this survey. Oral and written interviews were conducted at oral presentations and whenever the instructor met with each group before and after these presentations.

For the content knowledge survey, the first year class that was surveyed had twelve students (n = 12); second year had ten students (n = 10); and third year had eighteen students (n = 18). The sample was split into three time slices so as to glean unique experiences from each of them. In fact, the first time slice (spring 2004) consisted of those students already in the field, while the second time slice (spring 2005) consisted of those students who had just completed their education training, and the third time slice (spring 2006) consisted of students who were currently enrolled for the advanced GIS course. All of these study subjects used the same syllabi, the same case studies, and were taught by the same instructor.

The primary goal for conducting the content knowledge survey was to use it as an assessment tool for quantifying learning experiences from participating human subjects. The survey captured the attitudes of students after taking the courses based on three time slices: one group that took additional classes from other professors, another group included former students already in the job market; and the last one included a new group that was just beginning.

The instructor introduced the case studies to students at the beginning of the semester. They were required to work in groups of three-to-five students and were offered relevant materials covering each case. Excellent examples and illustrations of the case studies were also given and encouraged. Students were required to follow well-defined guidelines.

Grading rubrics for classroom and laboratory assignments, midterm examinations and student presentations, and SIUC official instructional evaluation tools were used as additional resources.

2.2 Survey instrument

An online survey questionnaire was designed to assess content knowledge. Table 1 shows the components of the content knowledge that was evaluated using a web-based survey instrument, Survey Monkey (http://www.surveymonkey.com). This instrument was used to design the survey, collect responses, and to conduct a partial analysis of the results. The motivation for survey instrumentation was based on the development of focused survey questions (Silverman, 2000) and assessment benchmarks developed by the National Science Foundation (NSF) Handbook for Project Evaluation (Westat, 2002). The web-based survey instrument gives an intuitive survey editor that enables a variety of questions ranging from single or multiple choice, matrices containing rating scales, drop-down menus to open ended - one line or essay/descriptive text to be framed. Its options allow for a systematic and logical flow of questions and a randomization of answer choices to eliminate potential biases. The survey can be accessed anywhere as long as the respondent has access to a computer with an Internet connection, is easy-to-follow and use, and is capable of maximizing the responses. A popup invitation generator allows for the respondents to be given automated email notifications and friendly reminders to complete the survey.

The compilation of responses was done using the same web-based survey instrument. The survey administration tool allows you to summarize the response data and generate basic descriptive. Individual responses were viewed and the use of inbuilt options such as filtering allowed the display of only specific responses of interest. The data was saved and uploaded into Microsoft Excel (Microsoft Inc., Seattle, WA) and Statistical Program for Social Sciences version 17.0 for Windows (SPSS Inc., Chicago, Illinois) for analysis.

3. Results

During the study period, they were 119 students who did the course. On average, about 15 students were enrolled annually. Figure 2 provides the average course evaluation and grading scores. The official SIUC Instructor and Course Evaluation Reports for evaluating teaching performance for the study period, for the Question on whether the course was taught effectively on a scale of 1 to 5 (5 being excellent), the overall average score was 3.8 for the eight years. Regarding whether the course was good, the average score was 4.0 confirming further what the instructor observed during learning process both in the laboratory and classroom. The nine laboratory exercises also corroborated the data because, on average, students earned 90% or higher during the study period. This was followed by coursework, where on average students scored 87 or higher, then the midterms and course project scored 82 or higher. Consistently, the overall average score for the key graded items was 85 or better while the overall average score for instructor and course evaluation was 4.2.

A total of forty human subjects were surveyed for content knowledge and the survey had a response rate of 65 percent. Of these 36 percent human subjects were drawn from spring 2004, 24 percent from spring 2005, and 40 percent from spring 2006 (Figure 3). The majority of subjects provided positive responses regarding pedagogical related questions and the usefulness of case studies. Overall, the findings are consistent with classroom grades obtained during the three year period. There was high level of enthusiasm and energy in the class. Although most of the students were able to adequately understand advanced GIS concepts some of the students remained confused regarding issues related to GIS data structures and algorithms. One of the students in additional comments noted that

Follow-up notes should be given to students by the instructor to address issues that were not covered by groups that were assigned specific topics. This approach should ensure that students receive critical information regarding the subject matter, even if the designated group did not cover the material entirely.

There was a general level of appreciation of GIS principles and concepts, but another student suggested the need for better direction of expectations advocating for properly defined learning outcomes. In a separate comment another student requested for additional reinforcement to the learning groups and the need for the instructor to clarify where there is an agreement or disagreement after the case study presentation.

An analysis of the short reports compiled over the study period revealed some interesting observations. Students with a main concentration in GIS were more willing to take on additional challenges, while graduate students, both at Master and PhD level, conducted more in-depth analysis and critiqued the material better than undergraduates. The conceptual learning groups provided more in-depth analysis and evaluation of GIS concepts in geospatial ontology than any other groups. Students with a solid science (especially with a biological knowledge) and a strong analytical background enjoyed the learning process better than those without it. However, a few students (on average 2-to-3 students every semester) lacked the motivation and energy to pursue this type of learning approach. Attendance during the study period was perfect or near perfect and most students engaged in the classroom discussion. The learning groups took the initiative to ask the instructor questions so as improve their understanding of topics and requested feedback on their oral presentations. Once the learning groups received feedback they took suggestions seriously and incorporated them into their final products.

Each learning group complemented the work of others, exhibited a strong commitment to their group and a strong work ethic and in the end most of the students provided positive feedback and suggestions, and they also understood the complexity and breadth of GIScience. Improvement in the level of thinking and evaluation of GIS concepts and technology was noted among the students, as well as there was increased interest in the subject matter and quality of presentation towards the end of the semester. The instructor had a keen interest in the lining of reasoning among students by reviewing whether the learning groups clearly stated the GIS concepts, the relevancy of illustrations and examples used, established clear goals and purpose of presentation, clearly evaluated the subject matter and assumptions, and mostly important knew the implications of the concepts on Homeland Security. Undeniably, a synthesis of the data showed high quality reasoning and intelligence among students; and the learning approach does encourage, engage, and provoke students to think critically as they explore and discuss the science and technologies behind GIS.

Table 2 provides a summary of the distribution of key measures of learning and teaching outcomes. Each of the three groups surveyed were very positive and satisfied with the learning objectives of this course and they also thought that the case-based approach was a superior technique in comparison to instructor-based lecture formats. In general, the study population was pleased with the GIS solutions in each case study at the end of the semester and appreciated its overall effectiveness and relevance to the wide area of the GIS field. The standard deviations were narrow suggesting a general agreement in the responses.

Table 3 illustrates the frequency distribution of respondents regarding learning and teaching outcomes. Over 70% of the respondents were in agreement as regards to the list of four items in Table 3. In response to pedagogical issues (reported both in Figure 3 and Table 4), the respondents expressed satisfactory outcomes and these were consistent with earlier observations in the official SIUC Instructor and Course Evaluation Reports that is more comprehensive than the survey results. A list of other measures is reported in Table 5. The respondents recommended that each group have a maximum of 3 members and only 36% of them preferred to work alone versus within a group setting.

4. Discussions

The teaching and learning of advanced GIS must be demystified through innovative and practical approaches using case studies and everyday life examples of applied GIS applications. The findings support the premise that a pedagogical approach based on a well-designed case study drawn from the natural setting facilitates the learning and teaching of complex GIS concepts (Savery and Duffy, 1996; Summerby-Murray, 2001; Drennon, 2005; Favier and Van Der Schee, 2012). In thinking about the case study teaching model, deliberate emphasis was placed on the seven principles for good practice in undergraduate education (Chickering and Gamson, 1991), which entail encouragement of student-faculty contact, encouragement of cooperation among students, encouragement of active learning, provision of prompt feedback, time management, the communication of high expectations, and the respect of diverse talents and ways of learning. Recent work in GIS education (Read, 2010; Yang et al., 2011; Ma, 2011; Dahal et al., 2011; Harvey and Kotting, 2011; Fagin and Wilke, 2011; Favier and

Van Der Schee, 2012) supports the development of an optimal design for inquiry-based, collaborative-based active learning approaches. The approach proposed in this paper has effectively responded to this call.

There is a downside of this approach though. The use of case studies and supporting exercises can be quite involving, demanding, and time consuming. Moreover, the instructor had to cover two other important topics. A convergence of all these materials can be barrier to the amount of reasoning development, as one respondent noted that the case study method, as developed at Harvard, is a proven superior method of introducing students to group dynamics, presentation skills, and research methods using real world scenarios in which to apply these skills. However, the single thing missing from a real world application is the aspect that someone in the group has to be "the Boss". Of course, no boss is required where everyone is aggressive and conscientiously carrying their assigned load. Being a non-Harvard minded student taking a GIS class at SIUC, this is difficult at best. In which this case study method is severely hampered and/or fails in GIS since getting all the various aspects of the project completed as a suitable quality final presentation in a timely manner is similar to herding kittens. The majority of the work falls on those few in the group who shoulder the responsibility of delivering a quality product on time. I would suggest modifying the current case study method for Advanced GIS by the instructor by appointing a group leader on a rotational basis—similar to what happens in real life or in work situations.

As another respondent remarked, a case study teaching model offers excellent opportunities for students to apply real world skill sets to a real world problem—unfortunately this opportunity is ignored by a few apathetic students whose workload then falls to the remaining responsible students in the group. Perhaps some students within a group should be voted off the case study island.

In spite of these shortcomings, the case study teaching model provides impetus for the development of pedagogical approaches that may facilitate the learning and teaching of geography through the use of computer-based instructional materials. The findings in the study should be interpreted within this context. Further development of this model, however, is required so that some generalization and replication can be done.

The findings support the use of a case-based modern-style pedagogical method because they do not only promote a student's desire to learn and discover new concepts, but also makes them to be actively involved in finding real world GIS solutions. The teaching method encourages, engages, and provokes students to think critically as they explore and discuss the science and technologies behind GIS. On the one hand the method creates an interactive dialogue between the instructor and the students while on the other hand it stimulates the learning process. Case studies developed from this study make classroom experiences more lively, attractive, relevant, and interesting.

5. Concluding Remarks and Implications

The curiosity to learn concepts and discover new knowledge using computer-based instructional materials, particularly among the young generation is enormous and should be exploited. Instructors teaching GIS should endeavor to include real world examples when discussing complex concepts and principles. A case study teaching may assist teachers in achieving this goal. Teaching technologically-oriented courses still possess numerous challenges. Even more challenging is being able to sustain the motivation of the instructor and students as there are "*no one size fits all*" solutions, but this instructional approach can be used as a basis to engage students and promote active learning in classroom environments. The instructor should constantly think about creative ways to present interesting case studies that have some bearing and meaning to everyday life. This will enable students to relate complex technological principles and concepts in GIS to real world solutions thus making the learning and teaching experience rewarding and successful. This may even help to increase student motivation, enrolment, and retention. For this approach to succeed, teachers need to be taught how to write successful cases backed with strong pedagogical methods.

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Table 1. Data Collected in Survey of Geog 420 Subjects

Section	**Examples of Questions and Information Gathered**
General Question (1)	• Semester in which subject took the course
Learning Objectives and Teaching Outcomes (4)	• Learning objectives for this course were well-defined • This is a better learning approach than instructor-based teaching • This course had reasonable solutions • The content (case study) is relevant to the subject matter
Pedagogical Matters (14)	• Case study provided excellent opportunity to Learn • Discovered new concepts and material • Interacted with students and promoted dialogue • Improved my GIS portfolio and problem solving skills • Promoted active learning and research skills • Improved oral communication • Case study was engaging and provoking • Enjoyed cooperative learning experience
Other Questions (5)	• Case study was useful and exciting • Recommend this course to other students • Size of group • Preferred to work as individuals • Liked my group/got along well with group

Both close and open-ended questions were used for collecting data. For close-ended choices, subjects were provided with a rating scale or multiple choice items.

Table 2. The distribution of measures of learning and teaching outcomes

Learning and Teaching Approaches	Mean Response Rates	Scale	Comments
Learning objectives for this course were well-defined	3.64±1.32 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Towards Agree
This is a better learning approach than instructor-based teaching	3.92±1.29 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Towards Agree
This course had reasonable solutions	4.12±0.60 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Agree
The content (case study) is relevant to the subject matter	1.92±0.76 SD	1-5 Excellent (1) to Horrible (5)	Excellent to Good

Responses support the fact that enrolled students taking Advanced GIS Studies course experienced positive learning and teaching outcomes, although a better recasting of learning objectives may be useful in the future as exemplified by a slight variation of the standard deviation (SD).

Table 3. The distribution of measures of learning and teaching outcomes by respondents

Learning and Teaching Approaches	Respondents with Positive Response (%)	Comments
Learning objectives for this course were well-defined	76	All the three groups were in agreement
This is a better learning approach than instructor-based teaching	72	All the three groups were in agreement
This course had reasonable solutions	88	All the three groups were in agreement
The content (case study) is relevant to the subject matter	84	All the three groups were in agreement

Over 70% of the respondents expressed positive attitudes regarding learning and teaching outcomes. However, there were no statistical differences among the three groups that participated in this survey regarding this matter.

Table 4. The distribution of pedagogical related responses by respondents

Pedagogical Responses	Mean Response Rates	Scale	Comments
Case Study Provided Excellent Opportunity to Learn	3.48±0.96 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Towards Agree
Discovered New Concepts and Material	1.36±0.70 SD	1-3 Yes (1) to Neutral (3)	Near Yes
Interacted with Students and Promoted Dialogue	4.04±0.74 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Agree
Improved my GIS Portfolio and Problem Solving Skills	2.16±0.80 SD	1-4 Excellent (1) to Poor (4)	Good
Promoted Active Learning and Research Skills	3.72±1.02 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Towards Agree
Improved Oral Communication	3.64±1.25 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Towards Agree
Case study was engaging and provoking	1.20±0.50 SD	1-3 Yes (1) to Neutral (3)	Near Yes
Enjoyed Cooperative Learning Experience	4.00±0.58 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Agree

As we can deduce from above, respondents agreed that the case study was engaging and provoking and that they enjoyed the cooperative learning experience as exemplified by the lowest standard deviation (SD). However, there were slight variations regarding whether the case study improved their oral communication. Overall, there were both positive and satisfactory outcomes regarding pedagogical approaches.

Table 5. The distribution of other learning measures by respondents

Other Questions	**% Respondents with Positive Response**	**Mean Response Rates**	**Scale**	**Comments**
Case Study was useful and exciting	88	4.00±0.76 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Agree
Recommend this course to other students	84	1.16±0.37 SD	1-2 Yes (1) to No (2)	Near Yes
Size of Group	72	2.64±0.91 SD	2-6+ 2 members (1) to 6+ members (6)	2 to 3 Members
Preferred to work as individuals	36	2.12±1.05 SD	1-5 Strongly Disagree (1) to Strongly Agree (5)	Near Disagree
Liked my group/got along well with group	84	1.16±0.37 SD	1-3 Yes (1) to Other (3)	Near Yes

They would recommend to the course to other students and also liked their groups as exemplified by the lowest standard deviation (SD). There was a slight variation among respondents when asked whether they would prefer to work alone.

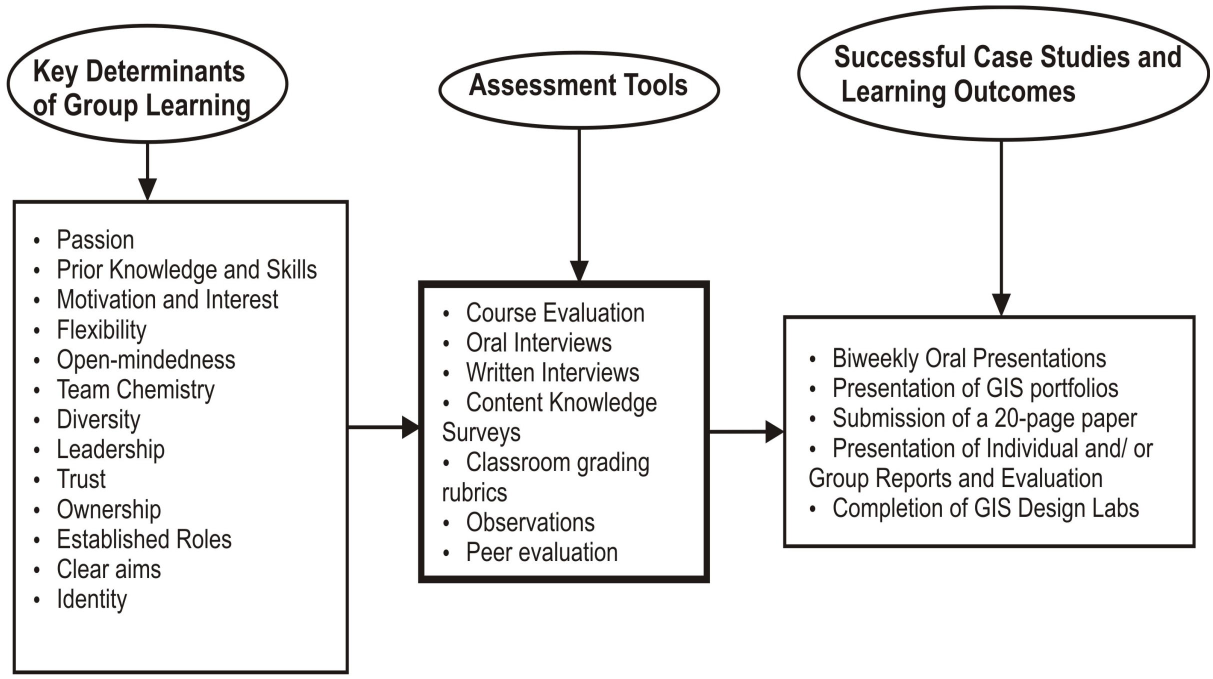

Figure 1. Presents the conceptual framework for a case-based modern-style pedagogical approach

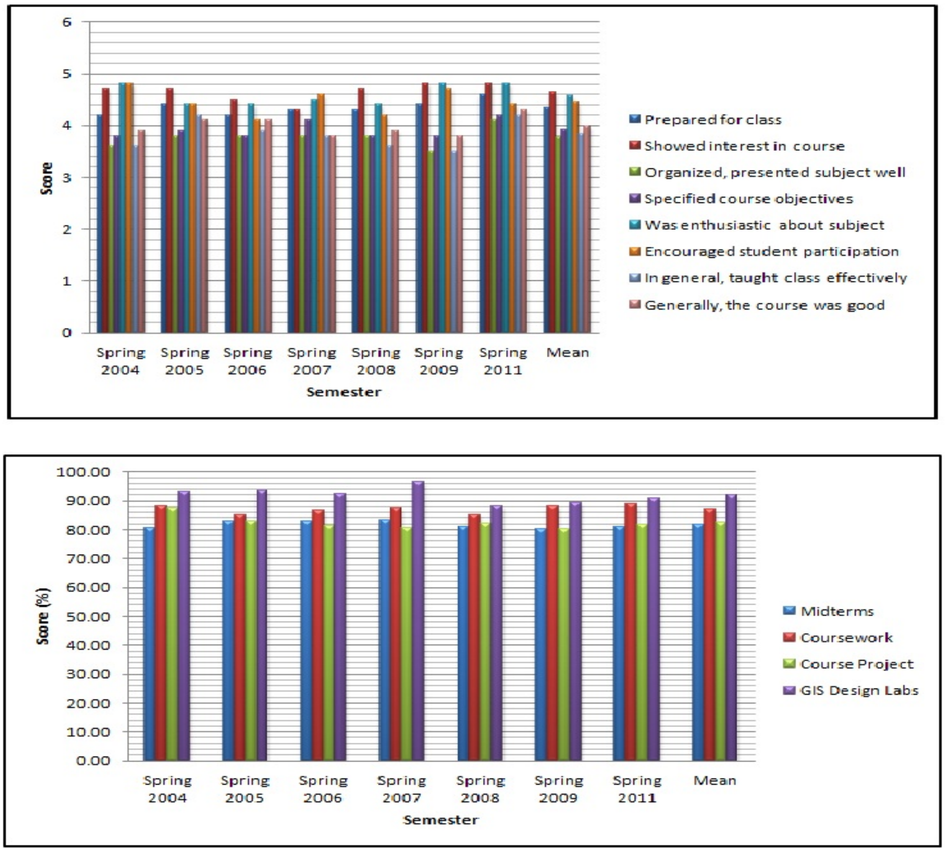

Figure 2. Upper panel provides course evaluation on a scale 1-5 (with 5 being excellent) while the lower panel gives the grades in four key areas with 100 being the excellent

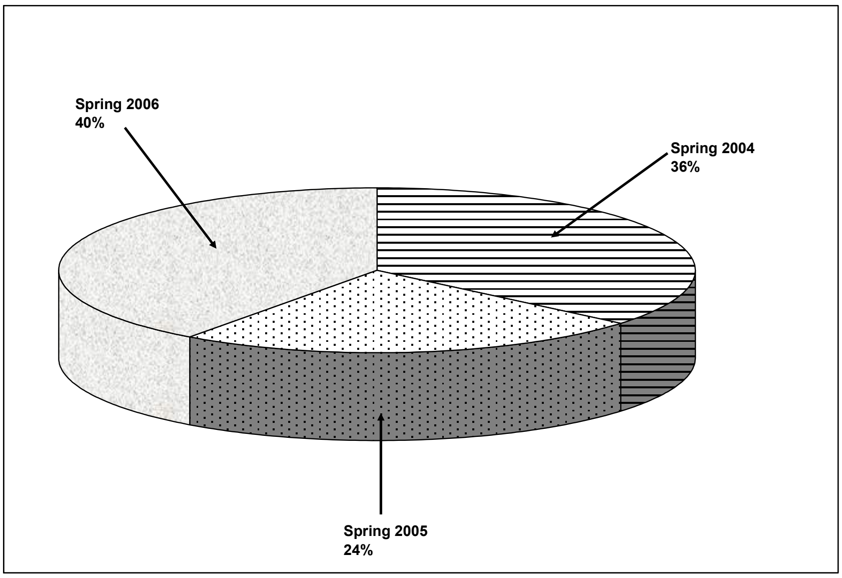

Figure 3. Illustrates the distribution of respondents by semester. There was an even distribution of respondents in this survey, although more interest was observed among the most recent group (Spring 2006) and the pioneers (Spring 2004)

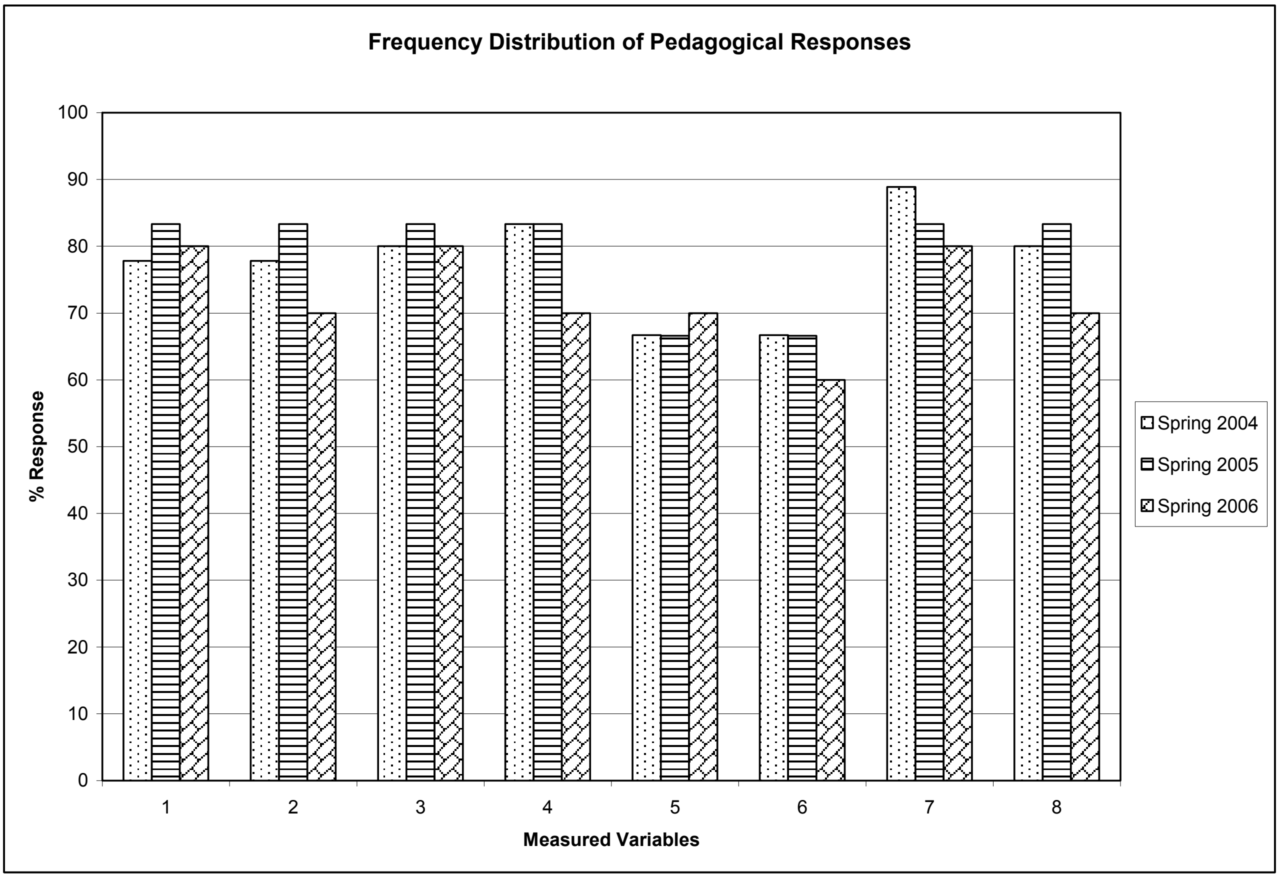

Figure 4. Shows the distribution of pedagogical responses by semester.

Legend to Measured Variables

1: Case Study Provided Excellent Opportunity to Learn; 2: Discovered New Concepts and Material; 3: Interacted with Students and Promoted Dialogue; 4: Improved my GIS Portfolio and Problem Solving Skills; 5: Promoted Active Learning and Research Skills; 6: Improved Oral Communication; 7: Case study was engaging and provoking; and 8: Enjoyed Cooperative Learning Experience

The majority of the respondents expressed both positive and satisfactory outcomes regarding pedagogical matters in this study. Case-based, real-world application teaching provided students with a great learning opportunity to explore advanced GIS concepts.

Appendix 1: Case Examples describing the Department of Homeland Security

Case I

Recent events that have been a major influence on the safety and security of the populace of the United States of America have led to the development, in November 2002, of a governmental entity known as the Department of Homeland Security. The department's primary goal is to prevent, protect, and respond to threats against the nation. This is enumerated in the department's mission statement: "We will lead the unified national effort to secure America. We will prevent and deter terrorist attacks and protect against and respond to threats and hazards to the nation. We will ensure safe and secure borders, welcome lawful immigrants and visitors, and promote the free-flow of commerce." The department was developed, in part, as a result of the lack of effective communication and interoperability between the various governmental agencies responsible for the safety and security of American interests. These agencies included the Federal Bureau of Investigation (FBI), Central Intelligence Agency (CIA), National Security Agency (NSA), United States Citizenship and Immigration Service (USCIS), United States Department of Treasury, United States Department of the Interior, Federal Emergency Management Agency (FEMA), among many others.

Much of the intelligence gathered by governmental agencies, especially time-sensitive data, will have a geospatial component. But due to the different backgrounds of the various governmental agencies, and the unique directions of their respective operations, they will often use different sets of terminology to describe the same concepts. This reduces the ability of the agencies to effectively communicate and impairs interoperability between the various data sets each agency maintains. Thus, the creation of a unified set of cognitive categories for the various agencies would be beneficial in allowing for more intercommunication and interoperability between the agencies. Consequently, there is a need to develop the prototypes of these unified ontologies, and to suggest how such a unified ontology should be implemented throughout the various government entities in the Department of Homeland Security and relevant state and local authorities. Although significant strides have been made to encourage intercommunication among the various governmental entities, the formation of such ontology will still be beneficial to the overall goals of the Department of Homeland Security.

Case II

In the wake of the September 11 attacks on the United States, Americans quickly realized the failures in U.S. Intelligence. The greatest problem evident that day was the lack of communication between agencies. The Central Intelligence Agency (CIA) and the Federal Bureau of Investigations (FBI), in particular, were unable to effectively communicate and gather intelligence that could have thwarted the horrible attacks that day. Shortly thereafter, President George W. Bush created the Department of Homeland Security. One of the major responsibilities of this new department was to effectively manage and oversee 22 U.S. agencies.

With this goal, two problems within the department became clear, (1) to be able to break down barriers and deregulate factors that lead to the inability to communicate between agencies and (2) help facilitate information sharing and bridge communication gaps and create intelligence-sharing procedures between agencies. An example of miscommunication and confusion was the breakdown of intelligence between the Federal Aviation Administration (FAA) and the Air Traffic Control System Command Center in Virginia during the 9/11 attacks. Specifically regarding Flight 93's hijacking over Pennsylvania, the evidence of confusion is apparent in taped conversation between the FAA and the Control Center of Virginia:

"FAA headquarters: They're pulling Jeff away to go talk about United 93.

Command Center: Uh, do we want to think about, uh, scrambling aircraft?

FAA headquarters: Uh, God, I don't know.

Command Center: Uh, that's a decision somebody's gonna have to make probably in the next 10 minutes.

FAA headquarters: Uh, ya know everybody just left the room."

(9/11 Transcripts: http://cgi.cnn.com)

With Homeland Security's clear focus on improving communication and intelligence sharing between agencies, there was an accompanying sense of accomplishment and of success. This accomplishment was illustrated by the fact that there has not been an attack on United States soil since, despite attempts. However, on August 29, 2005 hurricane Katrina slammed into New Orleans, eliciting outrage at the government's lack of quick and prudent response. There was a new realization that the government focused too exclusively on human inflicted destruction and not on the fury of "Mother Nature". Not only was there a lack of preparedness on the part of the government, but also a huge problem concerning the lack of knowledge of exactly what had happened to the city. Early on, they were aware of the hurricane's path and destructive winds, but the knowledge of the levee failures along Saint Bernard Parish in New Orleans did not become known to the government until much later. To further complicate the matter, many inner-city residents, many of whom were either too poor or elderly to be able to evacuate the city, were trapped. FEMA, several days after the catastrophe was unleashed, had to rely on the first-responders- local emergency response agencies to keep FEMA aware of what was happening within the city. First responders and city emergency response teams, with strained resources and under less than ideal conditions, had to try to communicate to FEMA the field conditions of New Orleans, but without a coordinated ability. This constituted another sign of intelligence failure; a problem with communication combined with a lack of knowledge of the geographic nature of the situation. Many local response agencies were aware of the places of levee failure, as well as where people were located stranded on flooded overpasses, yet were unable to effectively respond because of already strained local emergency response resources.