A CASE STUDY ON USING GIS AS A TOOL TO ENABLE LEARNING OF SPATIAL PROBLEM SOLVING ABILITIES IN AN ONLINE ENVIRONMENT

A Thesis

by

KENDALL CAROTHERS BALL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2009

Major Subject: Rangeland Ecology and Management

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Approved by:

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ABSTRACT

A Case Study on Using GIS as a Tool to Enable Learning of Spatial Problem Solving Abilities in an Online Environment. (May 2009)

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Chair of Advisory Committee: Dr. Douglas Loh

RENR 405 GIS Environmental Problem Solving is a course offered at Texas A&M University that focuses on enabling students' ability of spatial problem solving. For the past two years there have been modifications to enhance the teaching of spatial problem solving. One main change has been the use of introducing the use of scaffolding to improve the learning process.

Spatial problems are regarded as being unstructured. Scaffolding has been proven to help students in other disciplines solve this problem. This case study utilizes an innovative rubric to score students based on their abilities in their spatial thinking, subject knowledge, and coherence and organization. This rubric may be used in other contexts to score and evaluate other courses and their competencies in completing their stated objectives. The study proves that this approach facilitates students' cultivating their ability to solve spatial problems.

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CHAPTER I

INTRODUCTION

At Texas A&M University, RENR 405 GIS Problem Solving is a course that was originally taught on campus to around 20 students. Since summer 2006, RENR 405 has been delivered online in an effort to reach more students than ever anticipated. Throughout its implementations many situations have influenced the direction in which the course materials could be and have been improved to bring about students' learning potential of incorporating geographic information systems (GIS), e.g. ESRI®'s ArcMap®, to structure solution paths in solving spatially-referenced problems.. Carver, Evans, and Kingston (2004) stated that using a GIS to solve spatial problems helps students picture the impact of their decision. Carver, Evans, and Kingston (2004) is a case study of particular relevance and interest. This case is composed of 167 students at both undergraduate and graduate level. The report sheds light on the concept of usefulness of GIS for problem solving. It fell short of practicing the ideals, however. For example, students in the reported case study were not asked to manipulate data using a complex program like ArcMap® GIS. The research herewith carries forward the ideas Carver, Evans, and Kingston (2004) advocate. It has contemplated a more pragmatic approach that depict real-world problem solving in the spatial context.

A spatial problem is one in which many different factors are to be considered in a spatial context to solve a problem. Characteristically, a spatial problem is one that is

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This thesis follows the style of *Journal of Agricultural Education.*

categorized as being unstructured in nature. An unstructured problem is one in which there is no definitive path toward reaching a solution (Bigelow, 2004 ; Coulson & Saunders, 1987). An unstructured problem is also referred to as an ill-structured problem (Jonassen, 1997). Ge and Land (2003) state that if students are guided with a comprehensible framework, they are more likely to successfully solve an unstructured problem. Ge and Land (2003) also support the idea that cultivating students' abilities in framing a problem is more important than having peer to peer interaction. RENR 405 is designed with such a framing ability to help students learn how to solve spatial environmental problems.

Purpose of Study

The goal of this project is to establish whether or not, through all of the modifications to the course materials, the course is promoting the students problem solving ability.

Specific Objectives

a) To evaluate current course materials to improve students' ability in spatial problem-solving using a rubric based assessment

b) To assert changes needed in course materials to enhance the cultivation of students' ability in spatial problem solving

Methods

Students were given a midterm exam and a final exam on which the analysis for this study is based. The midterm and final exam were similar in the conceptual methodology section. However, the final exam gave students a chance to formulate a solution free of any format. The students' knowledge was assessed based on their ability to apply what they have learned about the use of GIS, in this case, ArcMap®, and what they have learned about structuring the problem solving process.

Objective 1: Evaluate the current course materials to improve the student's ability to problem solve using a rubric based assessment

The basic approach to assessing the effectiveness was based off of a similar rubric Wickersham and Dooley (2006). Their rubric was composed of five categories of skill level (beginning, developing, accomplished, and exemplary) and five criteria to evaluate the each individual student's work (Wickersham & Dooley, 2006). The rubric to evaluate student's skill in RENR405 was composed of the same categories of skill level. However, the criteria to evaluate the student's content were different due to the nature of problem solving that was taking place. The rubric produced a score. The score was then used to evaluate the student's ability to problem solve using ArcMap® as only a tool.

This approach was based off of two parts. The conceptual methodology was available in the midterm exam and in the final exam. This aspect was used as a comparison tool to evaluate if there was any improvement on an individual basis from the time of the midterm exam and the end of the course. This was also used to evaluate the course overall.

The final exam asked students to solve a problem from start to finish. This served as an overall evaluation of the student's ability to problem solve. By evaluating all aspects of the process there was also the ability to track individual learners and measure outcomes to uncover the course's weaknesses in an individual area of problem solving.

Objective 2: Evaluate if any changes to the course materials are necessary that would aide in the student's spatial problem solving ability.

The above results yielded the weaknesses and strengths of the course. With this information the materials were updated accordingly.

Theoretical Base for Study

Unstructured Problem Solving

An unstructured problem is defined by Ge and Land (2003) as having either unclear solutions or the information needed to solve the problem is not readily apparent. A spatial problem does not have a clear method of solving the problem. The main approach to solve a spatial problem is a top down approach (Carver *et al.*, 2004). The top in the top down approach is where the student will look at the broadest aspect of the spatial problem. As the students move down closer to the actual problem at hand the problem then becomes much easier to solve. This top down approach usually contains an unclear starting point and the order of the steps must be justified when a solution is reached. This unclear starting point supports the classification of a spatial problem as being unstructured. An unstructured problem also requires students to think about what steps they are taking and how this is affecting their potential solution (Ge & Land, 2003).

How a student learns to solve the problem and reaches a potential solution is based on his/her domain-specific knowledge and his/her comprehending of knowledge on how to structure the problem at hand. Domain specific knowledge is the basic knowledge of the problem’s context and a basic idea of what the problem is asking (Ge & Land, 2003). Generally speaking, this information may not be acquired from the problem itself (Jonassen 1997). With a foundation of the domain of knowledge alone the student may not be able to solve the problem without the structural knowledge of the problem (Ge & Land, 2003). Structural knowledge is represented by the student’s ability to assimilate data into a logical solution (Ge & Land, 2003). Together these two types of knowledge work together to shape a good problem solver (Ge & Land, 2003).

The Use of GIS to Facilitate Problem Solving

GIS is a tool to help students solve spatial problems (Carver, Evans, & Kingston, 2004). However, structuring of the solution path of a spatial problem may be done completely in the conceptual realm without the use of a GIS tool such as ArcGIS® (Carver et al., 2004). For example, Carver et al., (2004) developed a simulation of ArcGIS® that was believed to be easier for the student to use. Carver et al. (2004) sought to prove that spatial problem solving could be taught without the use of a large and cumbersome program. Carver et al., (2004) findings are supported by Jonanssen (1997) in that both of them have found students need some form of structure when tackling unstructured problems. Also there is a phenomenon in how the inexperienced problem solver will approach the problem by just looking at the surface characteristics of the problem rather than the finite details of the overall problem itself (Carver et al., 2004; Jonassen, 1997).

A GIS program, like ESRI's ArcMap®, can be arduous to a student because of the details of file systems and organization of data, yet it can also provide a hands-on approach to solving real world problems. Carver et al. (2004) uses the placement of a nuclear facility in the United Kingdom. Having a graphical user interface and a place where the student can see what their decisions are doing does have a significant impact on what types of solutions are formed when solving a spatial problem (Carver et al., 2004).

Hypothesis

It is assumed that each student enrolled into this course had some form of general problem solving experience. It was also assumed that each student has relatively little knowledge of a spatial problem. Therefore each student had equivalent problem solving ability and they were evaluated on an equal scale. By running analysis on the midterm it is assumed that each student has a beginning level of spatial problem solving ability by this point in the course. The students in RENR 405 will improve by at least one level in spatial problem solving ability as measured on the rubric.

Limitations

RENR 405 is a course that is presented online every semester. In the Spring of 2008 there were a total of 56 students actively enrolled in the course. Of the population of students only 37 were included to be a part of the evaluation because they completed all assignments. For the purpose of this study only the midterm exam and final exam were used as evaluation tools because other assignments had features that would identify individual students. The main weakness of this study lies in the fact that the sample was only a part of a single semester.

CHAPTER II

REVIEW OF LITERATURE

Characteristics of Unstructured and Spatial Problem Solving

In general, a problem falls into either a structured or an unstructured category of problem solving (Jonassen, 1997). A structured problem is defined as being a problem in which there is a finite pathway to the solution to that problem (Jonassen, 1997). However, an unstructured problem is defined as a type of problem solving that does not have a clear path to the solution (Coulson & Saunders, 1987; Jonassen, 1997).

Spatial problems fall into the unstructured category. A spatial problem is one in which there are multiple pathways to the solution (Carver et al., 2004). A novice and an expert in spatial problem solving will have distinctly different pathways in which they will solve a particular problem (Schunn, McGregor, & Saner, 2005). The novice will have a tendency to choose pathways that will not lead directly to the solution, however; an expert will have a tendency to solve the problem by using a pathway that is more direct to the solution (Schunn et al., 2005). The reason for this mostly attributed to the experience level of the expert verses the novice in this type of problem solving (Schunn et al., 2005).

A spatial problem is a multi-dimensional type of problem (Carver et al., 2004). Such dimensions include temporal situations and scale of the problem (Coulson & Saunders, 1987). GIS may be used to help students visualize what direction their decision pathway is taking (Carver et al., 2004). A problem with using GIS as a tool for solving such complex problems is that the program interface itself has a tendency to cause students to get confused over the workings of the program and the students will not focus on the problem at hand (Carver et al., 2004). This may be overcome by focusing on the problem solving aspect separately from the GIS program aspect (Carver et al., 2004).

The Use of Scaffolding as an Instructional Aide

A scaffold, in an instructional sense, is a tool that enables the instructor to promote the student's problem solving ability (Greene & Land, 2000). This support is required because a novice in a particular area of problem solving may lack the structural frame work to develop a sound analysis of the problem (Ching-Huei & Bradshaw, 2007). However, the support cannot be exact due to the unstructured nature of a spatial problem (Ge & Land, 2003).

Scaffolding may be implemented in two different ways. Social scaffolding encourages student to interact among themselves and the instructor, while embedded scaffolding is embedded in the course instructional materials (Greene & Land, 2000). Embedded scaffolding was the preferred method because it was found to be more effective than social scaffolding by Ge and Land (2003). Such prompting is executed by providing students with information that will encourage them to think past the surface of the question and have some form of justification for their answer that goes beyond the surface information (Ge & Land, 2003).

The overall goal of scaffolding is to provide a loose conceptual frame work for solving problems that is generic enough to be applied to most problems (Ching-Huei &

Bradshaw, 2007). The key to implementing such a learning tool is that the instructor needs to have limited interaction with the student to allow the student to think for themselves (Reiser, 2004). Scaffolding in the end should promote students to utilize their existing knowledge and the knowledge gained in the learning process to justify their answers (Ge & Land, 2003).

Problem Solving Rubric

The purpose of a rubric, as an evaluation tool, is to assess student work on a scale that is determined by the proficiency of a student in an area of study while making the assessment as objective as possible (Anderson & Puckett, 2003; Montgomery, 2002). This tool is more effective than conventional methods of evaluating students' performance because it can focus on an individual student's performance as well as the class as a whole (Ekman & Pelletier, 2008). In addition to helping the students learn, this process can help facilitate course improvements more effectively than traditional methods of assessment (Ekman & Pelletier, 2008).

When designing a rubric for assessing students' ability to problem solve, the rubric needs to be prepared in conjunction with the problem (Montgomery, 2002). In addition, the subject matter needs to be that of the real world that a professional in the particular field may face (Montgomery, 2002). The reason for this is that the students will gain an interest in the problem and they will have more of a basic knowledge of the problem at its most basic level (Levia & Quiring, 2008).

As a whole the use of a rubric makes an evaluation of a course as a whole more effective because of the way that each aspect of the course is broken down (Ekman &

Pelletier, 2008). The aspects of the course are to reflect the overall objective of the course and the desired learning outcome for each student (Levia & Quiring, 2008). With this tool an instructor may see how to change portions of the course materials in order to improve a portion of the course objectives (Levia & Quiring, 2008).

Evaluating Critical Thinking and Problem Solving Skills in the Spatial Context

Spatial problem solving requires the student to perform critical thinking to link all information associated with a problem to synthesize a resulting conclusion (Jablonski, 2004; Liu & Zhu, 2008). Jablonski (2004) proposes that the Big6™ method of problem solving be utilized to solve spatial problems.

The Big6™ method is broken down into six steps. They are (a) task definition, (b) information seeking strategies, (c) location and access, (d) use of information, (e) synthesis and (f) evaluation (Murray, 2008). The first step is the task definition which includes defining the problem and the identification of possible data needs (Jablonski, 2004). Defining the problem is further broken down into steps of developing questions about the problem at hand to help guide the student to a conceptual frame of the problem (Murray, 2008). The instructor may look at the definition of the problem and evaluate the organization of the definition to evaluate a student's performance in this area (Murray, 2008). Next, the student should seek out ways and locations to obtain the data needed for solving the problem (Jablonski, 2004). Each piece of data should be evaluated based on its priority and appropriateness in solving the problem (Murray, 2008). An instructor may look at the student's choice and evaluate the reliability of the source and the accuracy of the source to evaluate this step in the problem solving scheme

(Murray, 2008).Then each data source needs to be located physically; the previous step is just a brain storming exercise (Jablonski, 2004). In addition to physically locating each source needs to be searched within itself for more in depth information about the problem at hand (Murray, 2008). After this step in the Big6™, the acquired data should be examined for the accuracy of the source and the pertinence of the information to the problem (Jablonski, 2004; Murray, 2008). Next, the student needs to synthesize the data (Murray, 2008). This process includes utilizing technology to process the data into a meaningful form (Murray, 2008). This form could be that of a map or an image to support any possible solutions to the problem (Jablonski, 2004). Processing the data also involves the consolidation of data from multiple sources and possibly manipulating individual pieces of data to focus more on the scope of the problem (Jablonski, 2004; Murray, 2008). An instructor may focus on the process that a student uses to integrate their acquired data and how their understanding of their result is in the context of the target audience (Murray, 2008). The final step in the Big6™ methodology as applied to spatial problem solving is to evaluate the resulting information (Jablonski, 2004). This step also includes evaluating the overall process that was conducted to solve the problem (Jablonski, 2004). In this process the student should focus on the efficiency of the process as well as the effectiveness of the product in conveying a solution to the problem (Jablonski, 2004) .

Each step of the Big6™ can be individually evaluated for student competency (Murray, 2008). This is being implemented at a national level due the fact that information technology jobs are in high demand and the salaries for these jobs is exceptionally high (Murray, 2008). The instructors should implement this methodology into the evaluation techniques of student performance in a problem solving based course in order to provide a standard for evaluating students performance (Jablonski, 2004; Murray, 2008).

Structure of the Online Learning Environment

The online classroom is much different than the conventional classroom (Tallent-Runnels et al., 2006). The students need to know what is expected of them from the beginning of instruction and this must be presented in a very clear manor (McLinden, McCall, Hinton, & Weston, 2006). In addition to course objectives, the student needs to have a clear understanding of the timeline in which materials need to be completed (McLinden et al., 2006). This information allows the student to plan accordingly on how a particular course will need to be completed (McLinden et al., 2006).

Letting the student construct their own timeline to complete an online course is one to the incentives for a student to take an online course (McLinden et al., 2006; Tallent-Runnels et al., 2006). However, due dates are necessary to encourage student participation and to create a sense of tension that will ultimately encourage the students study required materials (Tallent-Runnels et al., 2006). This tension will also facilitate communication between students and the instructor (Tallent-Runnels et al., 2006).

Communication in the online environment may occur many different ways. The aspect of communication in an online environment needs to be one the primary concerns when designing an online classroom setting (Gaytan & McEwen, 2007; WinklerPrins, 2007). This communication is most commonly in the form of discussion threads, online streaming chat, and possibly video/audio conferencing (Tallent-Runnels et al., 2006). Course materials, such as exams, exercises, readings, ect.. , should promote this kind of activity (Tallent-Runnels et al., 2006).

Course materials and exercises should reflect that of the real world type of problems that professionals in the field of interest would encounter so that students may be able to relate (McLinden et al., 2006). This allows students to bring in their experiences and the students expect to solve meaningful problems (Kerr, Rynearson, & Kerr, 2006). The materials in addition to having the characteristics of a real world problem need to be focused into units (WinklerPrins, 2007). These units need to have a stepping stone like difficulty and build upon themselves as the student completes each unit (WinklerPrins, 2007).

With the culmination of clearly defined of objectives, readily accessible communication tools, and logically planned out course materials, the learning environment will become that of a place for interaction (Evans & Leinhardt, 2008). This interaction is being conducted online much like that of a traditional classroom (Evans & Leinhardt, 2008). The interaction creates the online environment that will facilitate learning and the exchange of ideas which the students would normally expect to find in a traditional classroom environment and some cases better than that of a traditional classroom environment (Evans & Leinhardt, 2008).

Specific Considerations for an Online GIS Learning Environment

A GIS learning environment for even a traditional classroom is a very expensive endeavor (Yap, 2008). The set up of an online environment poses part of this cost on the students because of the nature of the way a GIS course is conducted (Onsrud, 2005). The student is required to have a specific operating system and some basic knowledge of computing to set up their own GIS learning environment (Onsrud, 2005).

When creating the online learning environment for a student several items must be addressed. The student will require a high speed internet service because the data sets that each student may have to download can be very large (Onsrud, 2005). This particular problem may be eliminated by providing students with the majority of their data on CD or DVD (Yap, 2008). However the process of obtaining or creating their own data is a very important process that students should go through in a GIS course even thought this aspect of most courses is not usually addressed (Jablonski, 2004). In addition to high speed internet the students will need to allocate time for the GIS portion of the classes. This process can be time consuming because of constraints of their computing systems and this should be addressed in the course requirements (Onsrud, 2005). It is because of this time requirement and that some students are active professional seeking continuing educational credits that most findings have indicated that the online GIS student performs a good portion of their work on the weekend (Harris, 2003). For this reason an assignment posted on a Monday should not be due on the following Friday as to account for these two issues (Harris, 2003). On a final note, students need to be aware that there are possible problems the students need to know where to go if they have technological issues because a GIS system is a more complex system in comparison to other online learning environments and the instructor needs to have a very good back ground in this particular area in addition to the course material (Onsrud, 2005).

Reasons for Teaching GIS Online

One of the main constraints to teaching GIS in a traditional classroom is the number of computers and the time that a student has available to work on their work (Clark, Monk, & Yool, 2007). The other constraint placed on students in a traditional classroom environment is that the interaction between students and the instructor may be limited, but an online environment encourages this type of interaction (Hill, 1999). This interaction and availability of computing systems are the primary constraints in a traditional classroom environment.

Teaching GIS online has many different options as for the choice of software that may be used (Liu & Zhu, 2008). The choice of the software need to be that of which the instructor is very knowledgeable due to certain technical issues that may arise (Clark et al., 2007; Liu & Zhu, 2008). In an online environment the student is not limited to their potential time that they are allowed to explore the software and the conceptual applications of the GIS software in relation to the problem the student is trying to solve (Clark et al., 2007; Liu & Zhu, 2008). This will facilitate a learning environment that turns into a knowledge base for students to ask and answer questions which is necessary when learning how to solve GIS problems (Clark et al., 2007; Liu & Zhu, 2008).

This interaction will encourages an active learning environment (Hill, 1999). The active learning environment allows the student to be more in control of what they learn and how they learn which is an integral part of teaching GIS (Liu & Zhu, 2008).

The student in this active learning environment is then also encouraged to participate in discussion and interaction with other students trying to solve problems which will ultimately lead to critical thinking (Hill, 1999; Liu & Zhu, 2008).

By teaching online a student is more likely to try to interact with the instructor as well as their fellow students (Hill, 1999). This leads to a more student instruction led environment where the instructor facilitates, monitors, and guides discussion rather than the traditional method of lecturing to students (Hill, 1999). This allows students to develop and test their own hypothesis which will ultimately create a fully functional interactive learning environment (Hill, 1999; Liu & Zhu, 2008).

CHAPTER III

STUDY PROCESS

RENR 405 was a course that was originally an on-campus course. To put the course online, there was a need to modify the course materials for an online environment and certain aspects of the course were modified for use in evaluating the effectiveness of the course in teaching students how to solve spatial problems. After the materials were modified for an online environment, a rubric was created to evaluate the effectiveness of the course in relation to the course's overall main objective of teaching students how to solve spatial problems. Then the students were selected based on their completion of course materials and the rubric was utilized to evaluate the students. Finally statistics were used to determine the effectiveness of the course based on the resulting scores from the rubric that was created. This overall process is summarized in figure 1 which is a schematic representing this process.

Modification of Course Materials to Utilize Scaffolding

RENR 405 in its beginnings was a course that was more focused on the GIS technology steps of solving spatial problem solving than the conceptual spatial problem solving. The reason for this is that the course lacked the use of scaffolding that the students could utilize to understand and apply to most spatial problems.

The course was divided completely in two. There was a series of presentations that each student is to look at before even beginning to work the GIS program. The first part of these presentations was a portion of the conceptual framework to solve a spatial

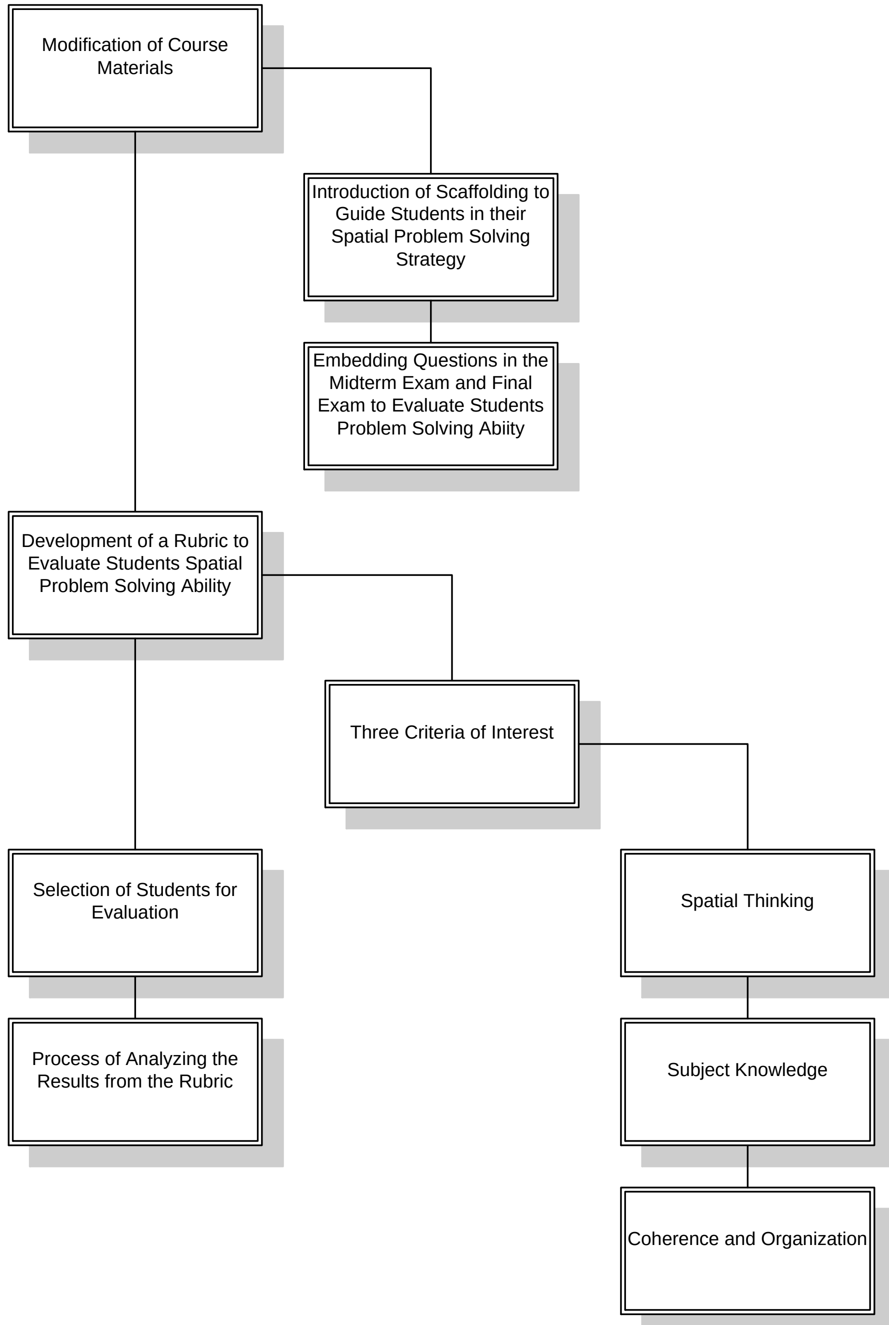

***Figure 1.* A schematic to represent the overall process in which this study was conducted**

problem (Figure 2). This occurred for the first five weeks. The second part of these presentations was over the basic background information of GIS and its associated data and the basic reasoning behind each step in each exercise. This process remains the same until week 5, when the student began learning more of the tools that GIS can provide them for spatial problem solving.

The Use of Scaffolding in Their Problem Solving Ability without GIS

Figure 2 illustrates the generic outline of how a student should perceive a spatial problem. In addition to reading about each individual step and analyzing given examples of each step, the students were asked to try to perform each individual step on their own. The method that they were taught how to perform each step was by starting out with breaking the steps down one by one each week. So for the first week they were asked to frame a given problem and the second week they were asked to perform step 2 on their own. Each week the problem remained the same but the steps change. This ensures that the student can build on their experience in solving the problem by using a problem that they were building upon their basic knowledge of the subject matter each week.

By the end of week 5 the student was expected to perform the basic steps and was given a chance to ask questions about any of the steps. In addition the student was asked to perform all steps up through step 3B (Figure 2). Step 3B was where the student combined their conceptual knowledge and their knowledge of GIS in solving a spatial problem (Figure 2). At this point a student was not expected to have a fully developed

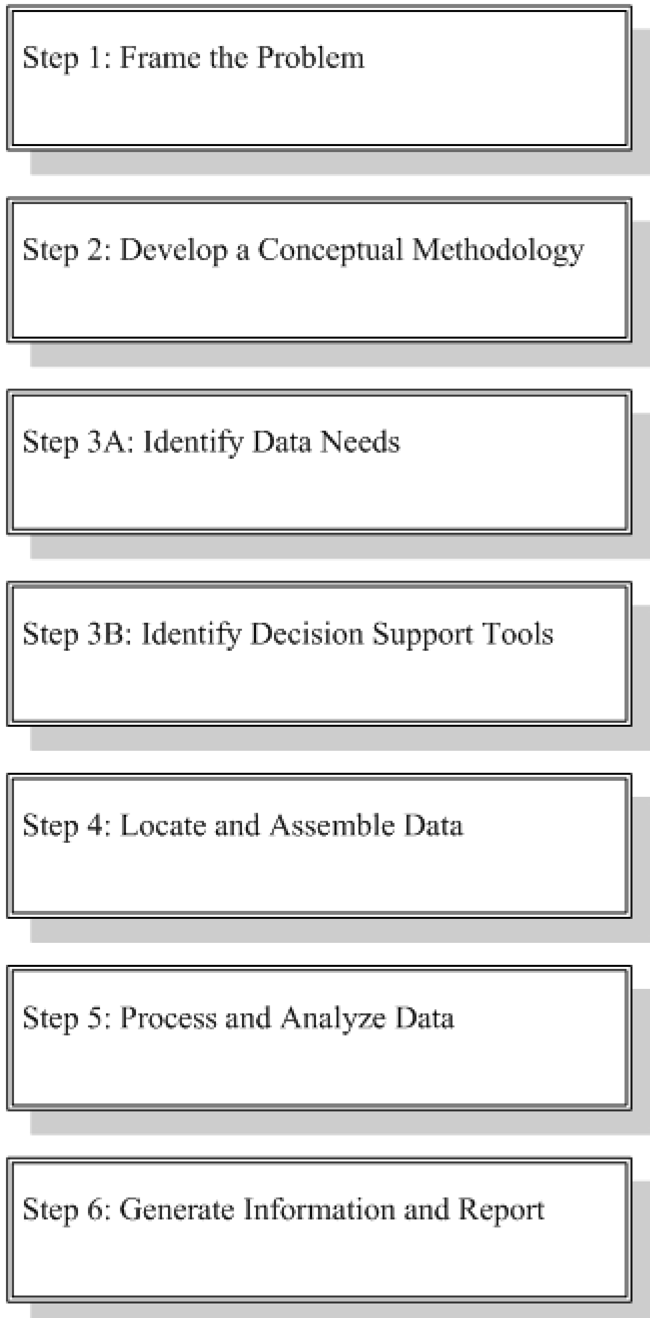

Figure 2. **The conceptual framework that a student used to help guide them through the spatial problem solving process**

sense of the tools that GIS offers to them in solving spatial problems. The reason that they were not asked to perform step 4 was that finding data for a spatial problem became a cumbersome task and was not the focus of solving a spatial problem solving, yet was a necessary skill (Figure 2). They were given a chance at the end of the course to perform step 6 when they developed their final projects (Figure 2).

The Use of Scaffolding in their Problem Solving Ability with GIS

The scaffolding that enabled the student to understand the use of GIS in conjunction with spatial problem solving involved the basic set up of the course. The GIS portion of the course was separated into two different problems. Each problem was differing in the spatial location and the type of problem that exist.

In the beginning of the course students were focused on Hurricane Katrina. The problem was used because almost all students can relate to this problem as it was a natural disaster the occurred during their life time. This means that the students had a good conceptual knowledge of what happened during the event. The materials broke the problem down into its basic major concerns and taught the students how to analyze the major concerns individually. In the end they learned the basic manipulation of the GIS program and had a clear understanding of how each tool applied to real world situations.

The last portion of the course had to do with a problem that was more abstract, but allowed the students to use their problem solving skills in a less structured environment. They were asked to determine what location that they would like to live using GIS. They were provided with a basic methodology of how to begin the analysis and left to be creative in how they answered where they wanted to live. This less structured environment allowed them to explore their potential skills that they had previously learned and expand upon their potential skills by exploring the GIS program beyond the course instructions. In doing so they were encouraged to try new ideas in the way of decision support tools (Figure 2).

Materials that Were Used to Analyze Students' Spatial Problem Solving Ability

Students throughout the semester were performing assessments that guided them on their problem solving ability. In the middle of the course and the end of the course students were asked to write down their problem solving steps given only a problem. The middle of the course was used as a benchmark for students' problem solving ability.

The midterm exam asked students to develop a conceptual methodology for solving two problems. The first problem dealt with a flood and the other problem dealt with potential water contamination of a river. In addition to developing their conceptual methodology, they were asked to justify their response. The justification and conceptual methodology provided insight on what their benchmark spatial problem solving ability was using a rubric to determine a score.

At the end of the course they were given given a problem, however this problem was located in France. Students were given an article about the problem to provide a conceptual knowledge base for what was going on. This ensured that everyone had the same knowledge of the problem. They were asked once again how they would solve this problem using GIS. In addition they provided a clear justification of why they solved the problem in the manner that they did. The same rubric was deployed again to score their answers and determine the end of course level of spatial problem solving ability.

Development of a Rubric to Evaluate Students' Spatial Problem Solving Ability

The rubric for evaluating student responses was created by looking at the conceptual way of solving a spatial problem. The format of the student's solution was not a part of the overall evaluation of their response. There were three main categories of interest: Spatial Thinking Skills, Content/Subject Knowledge, and Coherence and Organization (Appendix A). Each category had a maximum score of four points and a minimum score of one point. The students were ranked categorically in each area of emphasis with (a) Exemplary (4), (b) Accomplished (3),(c) Developing (2), (d) Beginning(1). By the midterm exam students were considered to be a beginning problem solver because they had already participated for seven weeks with solving spatial problems. For this reason the rubric started with a value of one instead of zero.

Spatial Thinking Skills

Spatial thinking was evaluated based partially on the content of a student's answer and the conceptual vocabulary that they used to justify their methodology. A student that was beginning in their spatial thinking alluded to a very general location of the problem at hand; while, a student with exemplary skills gave a very detailed description of the location by mentioning not only the geographic location, but the attributes of the location that help narrow it down. For example, a beginning student simply put the city and state when describing the location of a hazardous waste spill;

while, an exemplary student went into detail with the location of the spill, the city and state, and potentially affected individuals based on the type of waste spilled. Developing and accomplished learners were separated out by their justification of the problem. Their justifications included why they were using the information that they chose to support their methodology to be an accomplished student. The reason for this was that a developing student will be able to have a basic idea of what information they needed but they were lacking in the full explanation of why they really need to use that information for solving the problem. The justification and framing of the spatial problem were the primary aspects used to determine the individual student's spatial thinking abilities.

Content/Subject Knowledge

The subject knowledge was evaluated based on the student's answer in relation to the problem at hand. A beginning student had knowledge about the subject; however the knowledge or points they had about the topic did not seem to relate to the topic itself. For a student to have a rating of exemplary, they had to demonstrate that their knowledge was directly related to the problem at hand. Their response had to go beyond the given information. They should provide information that was not only beyond the question parameters but was also very pertinent to the question at hand. The differentiation between a student that was developing and a student that was accomplished was that the amount of essential information and the connections between that information. A student that was an accomplished level of knowledge demonstrated that the information provided supported itself and was essential to the question. An accomplished student had all of the essential information necessary to solve the problem. Overall the subject knowledge was based primary on the pertinence of the information the student provides and the connectivity of the information.

Coherence and Organization

The coherence and organization of a student's response played a vital role in evaluating their problem solving ability. A student that was beginning had a very disjointed response to solving the problem. These students' responses were in an order that was not logical. The order and disjointedness of the responses indicated that they are trying to solve the problem, but they did not quite grasp how they needed to solve the problem. However, an exemplary student provided a very clear flow to their justification and methods of solving the problem. They utilized transitions to help explain their flow and the overall appearance of the information followed a logical path from one step to the next. As for the accomplished student and the developing student, they were distinguished by the way they connected their ideas and their overall organization of their justification of the problem solving method. The coherence and organization was primarily based on the disjointedness of the answer and the logic of the order in which they solve the problem.

Selection of Students for Evaluation

The initial sample size of students was determined by the number of students that were enrolled in the course at the end of the spring 2008. Data was collected after grades had been turned in to eliminate any bias or influence on student grades. To remove further bias the students were assigned a random number and then the names were removed from all data. Furthermore, another random number was assigned to their previously assigned random number and this became the identification of each individual piece of data. The sample was narrowed down in order to produce more a homogenous sample of students. The reason for this was that in this case the interest was on students who had completed all course materials.

The midterm exam required that students justified their conceptual methodology. However, not all students provided a response and some replied not applicable. So these students were taken out of the sample because they could not be analyzed. In addition, students were asked to create a final project. Not all students completed such a project. These students were removed from the sample. If a student had not completed a final project then it was assumed they had not completed all course materials. Since they had not completed all course materials they had not completed all steps in learning how to solve spatial problems. Lastly, any student that did not complete a final exam was removed from the sample because they could not be analyzed. The overall sample size was 37 students out of 57 total students.

Process of Analyzing the Results from the Rubric

Analysis was performed on the class as a whole because the sample size is not large enough to justify an individual student analysis (Ott & Longnecker, 2001). The scores were lumped together and paired t-test were preformed on the mean value for each category as well as the overall score (Ott & Longnecker, 2001). The significance of the t-test was based on a 95% confidence interval with a p-value of 0.05 (Ott &

Longnecker, 2001). The reason that a paired t-test was chosen was because the idea was to test if there was a significance difference in students score after the midterm (Ott & Longnecker, 2001). The midterm was used as a benchmark for the students' problem solving level with the final exam serving as their post test.

CHAPTER IV

RESULTS AND FINDINGS

This study sought to determine whether RENR 405 students demonstrated a change in spatial problem solving ability as a result of using GIS (ArcMap®). The students' responses on both test varied between the midterm and final exam. Statistics were indicated that there was a significant difference between both midterm and final exams.

A Comparison of Students' Responses

Students' responses on the midterm exam and final exam varied tremendously in length of the response and the content. A summary of their scores categorized by criteria and overall score is provided in appendix B. Also provided is the original student responses that were used in this example explaining their responses located in appendix C.

Comparison of Midterm Exam Scores

Students responses varied on the whole spectrum of scores ranging from the beginning level to exemplary. The first example was a comparison of student 1066 and student 2173. Student 1066 scored an overall score of three while student 2173 scored an overall six. Student 1066 is at the beginning level of spatial problem solving and student 2173 is at a developing level of problem solving.

Student 1066 was at the beginning level of spatial thinking because they did indicate spatial and temporal scale by stating "After getting this information … we can see how much water has moved in the past years and see where the problem exist." The spatial scale was evident because student 1066 had previously, in their answer, defined the problem as the "flood plains" however; the reason that this was an example of a solution of a beginning spatial problem solver was that the student had no specific location specified. Student 2173 starts by stating "the problem lies with [sic] in the Brazos River…" By stating the Brazos River, Student 2173 provides a spatial reference to their problem that is easily found on a map. Student 2173 does try and provided a sense of order to their answer and narrowing by bringing in historical data, unlike student 1066. Overall student 2173 provided a more logical flow and better understanding of general subject knowledge than student 1066. Both answers lacked flow and consistency in nature. The use of run on sentences and fragments indicated a lack of coherence and organization, but student 1066 was more lacking in an overall flow to their answer in comparison to student 2173. This is why student 1066 received a score of one in each category and student 2173 received a score of two in each category.

In the second example, student 1175 scored an overall score of nine, accomplished level of spatial problem solving, and student 4602 score an overall score of twelve, exemplary level of spatial problem solving. These two students differed drastically than students 1066 and 2173 in their overall answer qualitatively. As for spatial thinking student 1175 stated, "You start broad by figuring the whole area of the Brazos River flood plain." This indicated that the student was clearly defining the project area as the Brazos River. Student 4602 takes this one step further by justifying their first step by stating, "…so that you can then determine the extent of the other data you need." Student 4602 kept in mind that the data would be narrowed by their first step while student 1175 had not even paid attention to the affect of scale on their data. Student 1175 concluded their justification with "…determine the amount of sludge that has been dumped and finally the concentrations of the sludge so that you can determine how big of a problem it will be." The confines of the problem were determined by the amount of sludge that had been dumped and the potential concentration in the Brazos River, so this student did not narrow the problem down spatially correctly. Student 4602 talked about sampling water to pin point problem areas. This was a good example of bringing in outside information to justify their answer. Student 1175 did use transitions between ideas but the flow was more apparent in student 4602 because they constantly referred to narrowing the problem area and refer to each step as though it was in a consecutive order for a reason. This was why student 4602 had an overall score of 12 and student 1175 had a score of nine.

Comparison of Final Exam Scores

Students on the final exam were given a chance of answering the spatial problem without any specifications or prompting on their responses. Students' responses varied in length and were vastly different in format. Some students provided an outline while some students provided an answer in an essay format with supporting charts to help explain their organization. The same samples of students from the midterm exam were graded using the same rubric. None of the students scored an overall three for their score on this portion of the course. For an example of how the rubric worked on this portion of the course, the same four students from the midterm were used as an example of how the responses were graded. This example includes students: 1066, 1175, 2173, and 4602.

Students 1066 and 2173 improved in their ability to solve spatial problems. Student 1066 went from a beginning level of spatial thinking to an accomplished level of spatial thinking and had an overall score of eight, while; student 2173, who had started at a developing level of problem solving, ended up at an exemplary level of spatial thinking ability and had an overall score of twelve. Student 1066 defined the location of the problem as “Arcachon Bay” while; student 2173 described the perimeter of the bay and the relative shape of the bay. Student 2173 provided a clear understanding of the spatial scale and its importance in solving spatial problems by describing physical characteristics of the location. Both students realized that this problem needed to be separated into multiple methodologies, however; student 2173 mentioned the chemical problem a separate issue from the oyster problem. Student 1066 recognized this but did not clearly distinguish the problems as being completely separate in nature. Student 1066 differs in their organization from student 2173 in that the ideas were not clearly connected and this was apparent because at the end they talked about how all of this information went together rather than showing this skill throughout the explanation. This is why student 1066 was still not fully accomplished in their spatial problem solving ability in comparison to student 2173.

Student 4602 remained at the same level of exemplary in their spatial thinking skills, while student 1175 decreased to a developing level of spatial thinking. The main difference between student 4602 and student 1175 was that student 4602 defined the project area spatially. Student 4602 clearly stated the project area as “Archon Bay, France” and in this case that was the problem area. Student 4602 went into further detail by defining where data may be collected while student 1175 did not even mention the idea of data needs. Student 1175 had a structure that was in the format of an outline but their methods were sparse and they were lacking a great deal of information in comparison to student 4602. Student 4602 went into defining the possible implications of the study in addition to providing a flow chart to help support their methodology. Student 4602 also divided the problem into separate parts like student 2173. Student 1175 did not recognize the separate parts of the problem. This is why student 2173 got an overall score of six and student 4602 received an overall score of twelve.

Statistical Results

A t-test comparing the overall score that was derived from the rubric and did have significant differences in the overall ability of students to solve spatial problems based upon spatial thinking, subject knowledge, coherence and organization (Table 1). This increase in the ability was visually apparent in the box plot comparing the three criteria. The criteria were also sub-divided into the midterm exam and final exam (Figure 3). Looking at the plots it was evident that one student was exemplary in the middle of the course as well as the end of the course for each of the criteria (Figure 3).

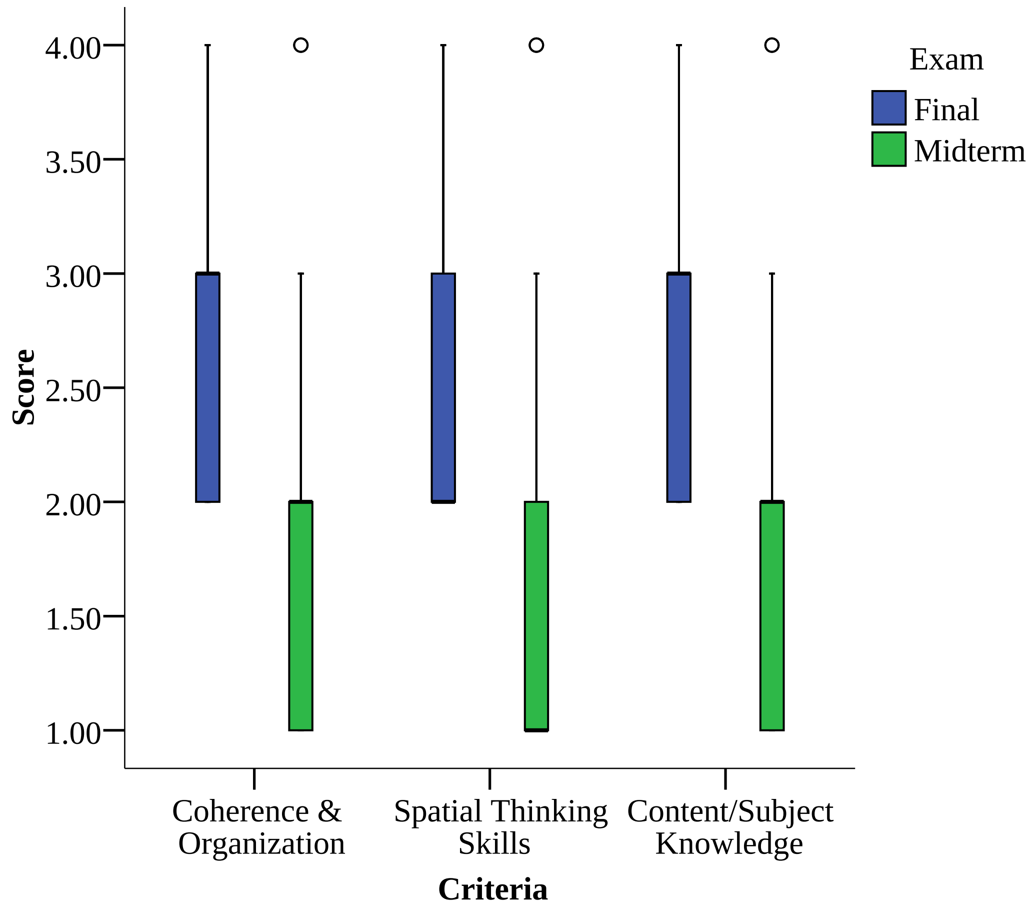

Figure 3. **Box plot comparing each criteria results of the midterm and final exam versus the final exam. (*n*=37)**

The overall score of students in this sample showed that there was significant improvement between the midterm and final, as shown in a t-test comparing the two exams (Table 1). This was also visually apparent in the box plot showing the midterm overall score and the final overall score (Figure 4). Also there was an outlier present in the case of the overall final scores as well (Figure 4).

Table 1

Comparison of the Overall Course Scores Broken Down by Criteria and Cumulative Scores

Paired Samples T-Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	ProblemSoving Midterm - ProblemSolvingFinal	-.91892	1.01046	.1661	-1.256	-.5820	-5.532	36	.000
Pair 2	SubjectKnowledge Midterm - SubjectKnowledge Final	-.91892	.98639	.1622	-1.167	-.5090	-5.167	36	.000
Pair 3	OrganizationMidterm - OrganizationFinal	-.91892	1.13965	.1874	-1.299	-.5389	-4.905	36	.000
Pair 4	MidtermScore - FinalScore	-2.67568	2.88727	.4747	-3.638	-1.713	-5.637	36	.000

Note. ***n*=37, *p* = 0.05**

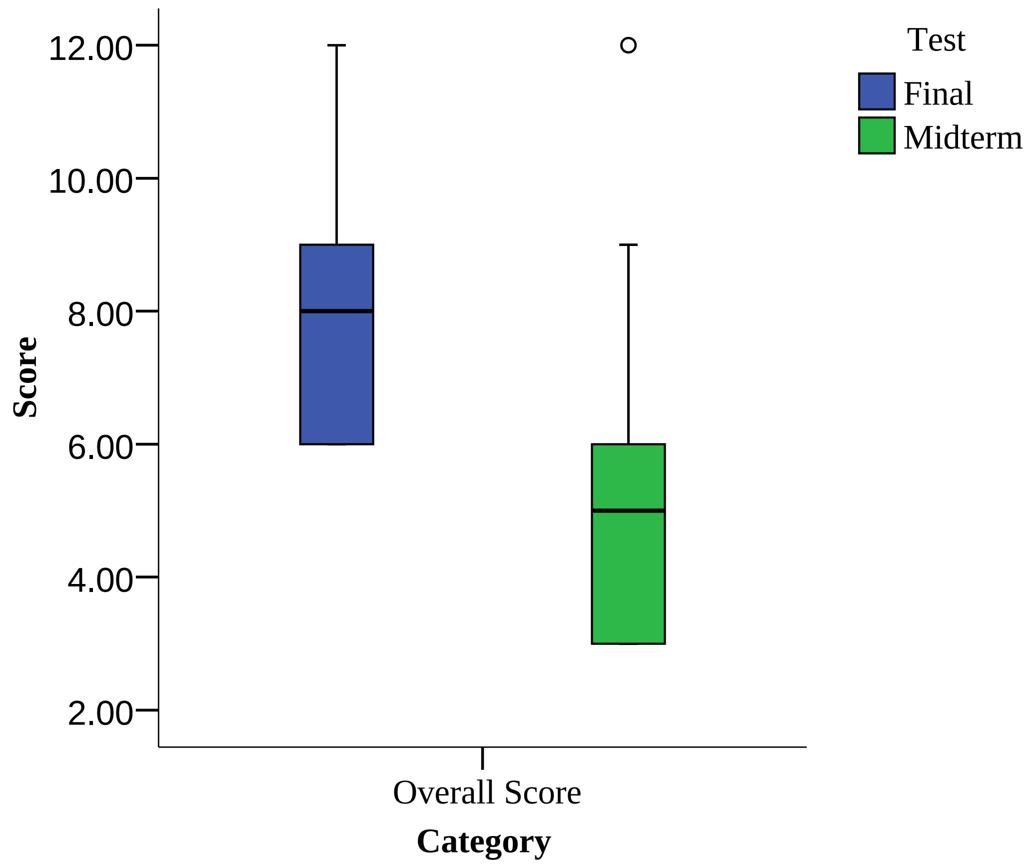

Figure 4. Box plot comparing each criteria results of the midterm and final exam versus the final exam (*n*=37)

CHAPTER IV

CONCLUSIONS

Summary

Purpose and Objectives

RENR 405 has been redesigned to facilitate the improvement of students' spatial problem solving ability. This study was the first step in establishing references on how a course could be designed to improve students' learning of spatial problem solving ability. By analyzing data on those students who had completed all course materials, it brought about an evaluation that helped identify deficiencies and areas for improvement in RENR 405.

Theoretical Support

Spatial problems fall into a category of problem solving that is called unstructured problem solving (Coulson & Saunders, 1987). According to Ge and Land (2003) scaffolding should promote the students ability to solve unstructured problems. The scaffolding should encourage the student to think outside of the surface material provided in the problem statement and devise a logical solution that is justifiable (Ge & Land, 2003).

In addition to scaffolding the use of GIS should help improve the students' ability to solve spatial problems (Carver et al., 2004). The reason for this is that a GIS program allows a student to see the immediate effect of their decisions in the process of solving a spatial problem (Carver et al., 2004). The visualization helps a student become more spatially oriented in their thinking and reasoning (Carver et al., 2004).

Limitations

RENR 405 is a course that is presented online every semester. In the spring of 2008 there were a total of 56 students actively enrolled in the course. Of the population of students only 37 were included to be a part of the evaluation because they completed all assignments. For the purpose of this study only the midterm exam and final exam were used as evaluation tools because other assignments had features that would identify individual students. The main weakness of this study lies in the fact that the sample was only a part of a single semester.

Summary of Methodology

Students were selected from the spring 2008 class based on their completion of all course materials. This included a completed midterm exam and final exam. Any other portions of the course materials were left out because they had material that could be identifiable back to individual students. If a student did not complete any portion of the course material then they were eliminated from the sample.

This sample of students was then randomized to eliminate any bias in the study. After bias had been eliminated each of the students' responses on the midterm exam and final exam were evaluated individually and a score was recorded. This score was generated using a rubric based on the student's spatial thinking ability, subject knowledge, and coherence and organization of their answers. Each category was worth four points. Students are classified at four levels. A beginning level was a score of one or overall three and an exemplary level is a score of four or overall of twelve.

The the individual categories were then analyzed using statistics. The statistical method used was a paired t-test. This test was used to compare the results of the midterm exam to the final exam categorically and holistically.

Key Findings

The study found that the students as a whole were improving their problem solving ability with a p-value of 0.05. In addition there was no need for any further changes to the current course materials.

Conclusions

The course did prove to be an effective way of enhancing students' ability to solve spatial problems. More importantly the rubric proved to be a very effective tool in evaluating the students' ability to solve spatial problems. Also, as the results indicated, there was no need to make any changes to the current course materials.

Enhancing Students' Spatial Problem Solving Ability in RENR 405

RENR 405 did promote the students ability to solve spatial problems. The results indicated that there seemed to be a little bit of confusion among students on the midterm in terms of spatial thinking. This could be due to the fact that they have only been briefly introduced to this for only seven weeks prior. Also the learning environment was more structured for the first seven weeks. This structured environment did not allow the student to explore their problem solving ability without some form of scaffolding or feedback. In the latter half of the course a student was allowed to be more creative in how they solved problems. They were allowed to go beyond just pushing buttons as supported as an effective method for teaching spatial problem solving (Jablonkski, 2004). Also Jablonski (2004) comments on how most GIS courses do not teach this aspect of letting the students solve problems utilizing their own creativity. The students, by the last portion of the course, had a more extensive vocabulary to utilize when explaining how they solved a spatial problem. This could have caused the increase in the students' spatial problem solving ability because if they do not really know how to describe what they were doing then they would not be able to solve a problem. This would represent an increase in their subject knowledge. By this point in the course they had more experience in solving spatial problems. Most students by the end of the course had a very good understanding of how a spatial problem needed to be structured in order to solve the problem. So their coherence and organizational skills increased. Over all the students performance in spatial problem solving improved but it was inconclusive without further testing as to why their ability improved.

Effectiveness of Using a Rubric to Evaluate Students' Spatial Problem Solving Ability

The rubric, which was utilized to evaluate students' problem solving ability on the midterm and final exams, was an effective tool for evaluating the course's effectiveness as a whole. The reason that this tool was more effective than using another method was that the rubric made sure that each student's response was evaluated based on the same standards as other students. This made the results for each individual student uniform in the evaluation of their spatial problem solving ability. By making the results uniform, the course could be evaluated as a whole for its effectiveness in promoting students spatial problem solving ability. Without such a tool the results would not have been accurate (Levia & Quiring, 2008).

Evaluation of Need for Changing Any Portion of the Course Materials

The results of the evaluation of the students' responses on the midterm exam and final exam indicate that RENR 405 was effectively teaching students' spatial problem solving ability. The results on the midterm could have been because students had only received seven weeks of instruction on how to solve spatial problems. Also in this seven week period the students were in a very structured environment in comparison to the last half of the course. This more structured environment could have made students less able to construct and express the way that they would solve a spatial problem. However, the final portion of the course was where the students were encouraged to be creative in their final project. This creativity may have induced them to conceptually and mechanically develop their spatial problem solving ability. In addition the students had five more weeks of instruction on solving spatial problems and they had been more exposed to the vocabulary that was used to describe how to solve a spatial problem. This could be the cause of the increase in the ability of the students' spatial problem solving ability in the last half of the course.

Implications

Spatial Problem Solving

The use of scaffolding to promote students problem solving ability may have been evident. However, in a spatial context the students need to be able to relate to the problem visually. They need to be able to have a physical means for solving these problems and they need to have some form of scaffold to solve the problem, as is provided in this case. The conjunction of students working on two different problems utilizing software and having to think about problems without software proves as a viable approach to presenting spatial problem solving. But the effects of this are inconclusive and further testing needs to be preformed.

Using a Rubric for Evaluation

By utilizing a rubric for evaluating students' problem solving ability, the instructor has the ability to break a course down into it elemental parts. This made course improvement much easier to pin point in comparison to looking at a course's final grades. A rubric also may have implications in the fact that it not only categorizes an evaluation but it makes the information received from an evaluation more tangible than traditional means.

Future Research

The results of this study were based on a whole class. This was a good way to evaluate a course, but looking at the individual student's data and trying to group the data would be more beneficial for making a final conclusion. This study was limited in sample size because it was conducted for only one semester. Also a study of the students needs to be done without GIS or scaffolding to find if this makes a significant difference in student performance. This future study could potentially be used to delimit a cause of the increase in the students overall ability to solve spatial problems. Results would also me more conclusive if the study were done over several semesters to increase the sample size.

The study was limited to this case, a case in which the students were only in an online environment. These students were only being taught by using scaffolding and GIS. The students could be taught without scaffolding or without GIS to see if there are any significant differences in student performance. The study could be broadened by taking a look at similar courses and using the same test on those students. This would provide a comparison to see if scaffolding or GIS is really having that much effect on the students'ability to spatially problem solve.

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APPENDIX A

RUBRIC FOR EVALUATING STUDENT RESPONSES

Problem Solving Rubric

Criteria	**Exemplary**	**Accomplished**	**Developing**	**Beginning**
Points Possible: 12	**4**	**3**	**2**	**1**
Spatial Thinking Skills**	Discussion incorporated clearly the use of spatial scale as related to the overall methodology throughout the discussion with a clear justification.	Discussion incorporated the relatively apparent use of spatial scale as related to the overall methodology throughout the discussion with a relatively clear justification.	Discussion incorporated the use of relatively unclear use of spatial scale as related to the overall methodology throughout the discussion with a poor justification present.	Discussion only provides a general idea of the study area and lacks the ability to narrow the subject matter down to a conclusion lacking justification.
Content/Subject Knowledge	Addresses the question completely and in-depth; points are all clearly made and all evidence supports arguments/rationale; clearly has grasp of content and elaborates with explanation and examples	Sufficient information that relates to the topic; includes essential accurate information that satisfactorily addresses the question/topic.	Includes some essential information and begins to address topic/question, but great deal of information is not clearly connected.	Points not clear; information included does not support topic in any way; does not have grasp of information.
Coherence & Organization	Information clearly stated and developed; specific examples are appropriate; conclusion is clear; flows well together in a logical order; good transitions; succinct but not choppy.	Majority of information is presented in a logical sequence; generally very well organized, but better transitions from idea to idea are needed.	Concepts and ideas are loosely connected; lacks clear transitions; flow and organization choppy.	Posting is disjointed and choppy; does not flow; development is vague and illogical in order.
/ 12 Points				

***** See second page for explanation of spatial and non-spatial thinking skills indicators***.

Indicators of spatial (+) and non-spatial (-) thinking within student solutions

Indicator	+	--
Relevance	Relevant statements	Irrelevant statements, diversions
Importance	Important points/issues	Unimportant, trivial points/issues
Spatial descriptors	• Location of problem • New ideas that delineate problem • New ideas that may help define potential problematic areas • Bringing new things in that support/justify the solutions	• Repeating what has been said in the problem statement • False or trivial leads • Squashing, putting down new ideas
Bringing outside knowledge/experience to bear on problem	• Drawing on personal experience • Refer to course material • Use relevant outside material • Evidence of using previous knowledge • Welcoming outside knowledge	• Sticking to prejudice or assumptions • Squashing attempts to bring in outside knowledge
Ambiguities: clarified or confused	• Clear, unambiguous statements • Discuss any ambiguities to clear them up	• Confused statements • Continue to ignore ambiguities
Linking ideas, interpretation	• Linking facts, ideas and notions • Generating new data from information collected	• Repeating information without making inferences or offering an interpretation • Stating that one shares the ideas or opinions stated, without taking these further or adding any personal comments
Justification	• Providing proof or examples • Justifying solutions or judgments	• Irrelevant or obscuring questions or examples • Offering judgments or solutions without explanations or justification
Width of understanding (complete picture)	• Widen discussion (problem within a larger perspective. • Intervention strategies within a wider framework.)	• Narrow discussion. (Address bits or fragments of situation. • Suggest glib, partial, interventions)

APPENDIX B

RAW STUDENT SCORES

Raw Midterm Exam Scores

ID	Spatial Thinking	Subject Knowledge	Coherence & Organization	Overall Score
1066	1	1	1	3
1175	3	3	3	9
1602	1	1	1	3
1981	1	2	2	5
2173	2	2	2	6
2375	2	3	3	8
2660	1	1	1	3
2706	3	3	3	9
2795	1	2	1	4
2823	1	1	1	3
2926	2	2	2	6
2934	1	1	1	3
3020	2	2	1	5
3964	1	2	2	5
4308	1	2	2	5
4346	2	2	2	6
4602	4	4	4	12
4818	2	2	3	7
5466	1	1	1	3
5578	2	2	2	6
5960	1	2	2	5
6153	1	1	1	3
6213	1	1	1	3
6328	1	1	1	3
6437	1	2	2	5
6621	2	3	3	8
6913	1	2	2	5
7475	4	4	4	12
7547	1	1	2	4
7886	1	2	1	4
8002	2	2	1	5
8019	1	1	1	3
8041	2	2	2	6
8167	1	1	1	3
8552	2	2	1	5
8615	1	2	1	4
8920	2	2	3	7

Raw Final Exam Scores

ID	Spatial Thinking	Subject Knowledge	Coherence & Organization	Overall Score
1066	3	3	2	8
1175	2	2	2	6
1602	2	2	2	6
1981	3	3	3	9
2173	4	4	4	12
2375	3	3	3	9
2660	2	2	2	6
2706	2	2	2	6
2795	3	3	3	9
2823	3	3	3	9
2926	2	3	3	8
2934	2	2	2	6
3020	2	2	2	6
3964	2	3	4	9
4308	2	2	2	6
4346	4	4	4	12
4602	4	4	4	12
4818	2	3	3	8
5466	3	4	4	11
5578	2	2	2	6
5960	2	2	2	6
6153	2	2	2	6
6213	3	3	3	9
6328	2	2	2	6
6437	2	2	2	6
6621	3	3	3	9
6913	2	3	3	8
7475	2	2	2	6
7547	2	2	2	6
7886	3	3	3	9
8002	3	3	4	10
8019	2	3	2	7
8041	2	3	2	7
8167	2	3	2	7
8552	3	3	3	9
8615	4	3	4	11
8920	2	3	4	9

APPENDIX C

SAMPLE OF STUDENT'S RESPONSES

Student 1175

RENR 405

In order to create a pathway for conceptual methodology there is certain information that must be gathered beforehand. You must first decide what the problem is as well as its location. You must then pinpoint what qualifies as the information of interest. Finally answers must be found supporting both quantitative and qualitative criteria. Quantitative answers will be answers that provide specific answers such as concentrations of TBT while qualitative answers refer to a more broad area such as overall or estimated environmental impact. In other words, qualitative answers are those that are hard to measure exactly. When developing the conceptual methodology it is important to start from a broad perspective and work down to focus in on the specifics.

Identify the Question:
How has TBT affected oyster populations in Arcachon Bay?

Location:
Arcachon Bay

Information of Interest
Adverse Affects on Population
Location and amount of infrastructure damage
Total amount of TBT

Quantitative Answers
Concentration of TBT in various Oyster grounds
Overall estimated concentration of TBT in the Bay
Estimate of TBT caused oyster loss

Qualitative Answers
Potential effects on life due to TBT
Overall conditions of the quality of the environment

Creation of Conceptual Methodology
*Initially, a map should be developed of the entire area including not only the oyster grounds, but the marinas and mooring areas as well.

*To decide the effect that TBT is having on oyster production, concentrations of TBT should be measured as well as oyster numbers throughout several locations in the Bay.

*Combine data together to discover total amounts of TBT in the Bay as well as in which regions the TBT is having the most influence on oyster production.

MidtermSelect						
ID	**Attempt**	**Fertilizer Plant: Conceptual Methodology (Matching)**	**Week 2: Fertilizer Plant Methodology Justification**	**Lake Limestone: Conceptual Methodology (Matching)**	**Week 2: Lake Limestone Methodology Justification (Paragraph)**	**Grade**
	1	b, c, e, f, a, d	You start broad by figuring the whole area of the Brazos River flood plain. Then you use historical data to figure where the water levels would rise to have an affected area. After you have narrowed this down you would determine where there are human and wildlife populations so you can look to see where you have problems. THen you would overlay the information so areas of major concern are apparent. Next you would determine the amount of sludge that has been dumped and finally the concentrations of the sludge so you can determine how big of a problem it will be.	b, a, e, f, c, d	You would begin again by starting broad by figuring out the flood plain of the Navasota River. You would then figure out exactly how much water you are dealing with so you know how big a problem it might be. You would then focus in further by finding areas where the water may cause pooling problems and then overlay this data to see major areas of concern. You would then figure populations and finally infrastructure to see which of these flooded areas will have problems for people and infrastructure.	
	2	b, c, a, d, e, f	First you would look broadly by figuring out the entire flood plain and continue looking broad by determining where affected areas were in the past. Next you would figure out the amounts and concentrations of the sludge dumped. Populations would then be focused in on to discover where there could be severe problems and finally all data would be overlayed to see where true problems will be.	b, a, e, f, c, d	First determine the broad flood plan and the amount of water that broke through that may cause damage. Then geographically mark low laying areas where water may pool up and create problems. Overlay all this information to discover which areas are going to be problem areas. Finally look at populations and infrastructures to see if they are in the areas that are affected heavily	

Student 1066

MidtermSelect						
ID	Attempt	Fertilizer Plant: Conceptual Methodology (Matching)	Week 2: Fertilizer Plant Methodology Justification	Lake Limestone: Conceptual Methodology (Matching)	Week 2: Lake Limestone Methodology Justification (Paragraph)	Grade
	1	e, b, a, d, c, f	First the population would need to be located, then the flood plains should be mapped out.Next, the amount of sludge and it possible concentrations should be evaluated. After getting this information than we can see how the water has moved in the past years and see where the problem exists.	d, b, a, e, c, f	The location of the problem should be located(infastructre) and the areas below the infastucture. Along with the data that is related to each subject is determined. Finally the affected population is determined.	

RENR 405
Final Exam

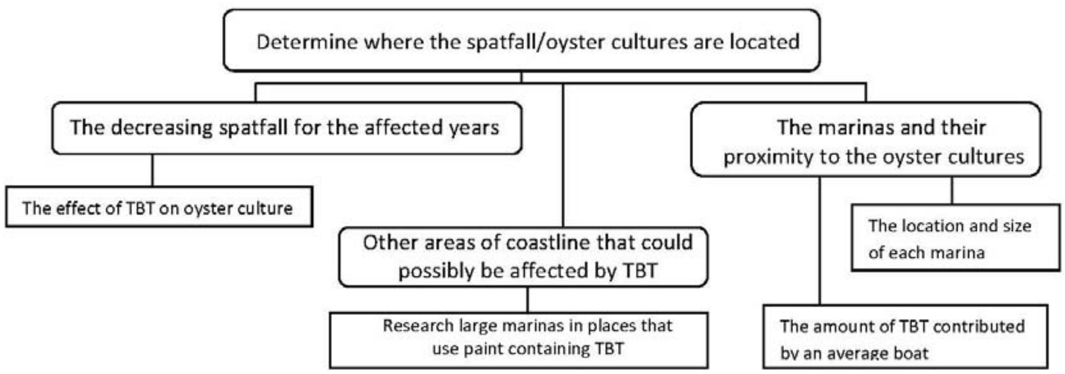
Claude Alzieu

In the early 1980's, multiple bays along the coastline of France experienced a decrease in their production of their booming oyster industry. It was soon discovered that one reason for this decrease was due to high tributyltin, or TBT, levels. These high TBT levels were caused by TBT based paint coming from hundreds of boats in the marinas. Regulations were soon created to prevent the use of this TBT based paint from harming the marine life.

This article refers to a specific bay on the coast of France called Arcachon Bay where oyster production can be traced back to the 1700's. Some areas of interest to be concerned with are: the number of oyster cultures affected (spatfall), the number of boats per marina relative to the spatfall numbers, the economic impact of the community, and the French regulations that were put in place to stop this problem.

The methodologies for this problem are as follows:

1. The decreasing spatfall for the effected years
2. The marinas and their proximity to the oyster cultures
3. Find other areas of coastline that could possibly be affected by TBT



The ArcGIS program can be used to document the location and regression of the size of the oyster cultures as well as the distance and sizes of the marinas on the bay. Ultimately, with this information we will be able to provide a correlation between the amount of boats at each marina and how the oysters have been affected. Data would be needed to find an estimate of the TBT concentration contributed by each boat. With this information, the amount of TBT contributed by each marina will surely show how it has affected the nearby oyster cultures.

Arc Maps can be used to show not only the decrease in oyster numbers before the regulations, but also show the increase back to average oyster numbers once the laws were put into place. This could possibly persuade other coastal countries to implement similar laws, ultimately saving marine life across the globe.

Student 4602

MidtermSelect						
ID	Attempt	Fertilizer Plant: Conceptual Methodology (Matching)	Week 2: Fertilizer Plant Methodology Justification	Lake Limestone: Conceptual Methodology (Matching)	Week 2: Lake Limestone Methodology Justification (Paragraph)	Grade
	1	a, b, c, d, e, f	In the first step you must determine the amount of contamination so that you can then determine the extent of the other data you need. To narrow down further, determine the floodplain of the region. Narrow further by getting historical water levels (chances are the contamination has not traveled out of the water, so it should only be where the water has been). Sample water to pin point problem areas. Then locate populations within the area you narrowed down. Overlay everything to determine where the problems are (with wildlife and humans).	a, b, e, c, d, f	Step one determines how much water you're dealing with so that you can define the affected area. The area is within the flood plain, so you narrow down which populations to look at by determining that. You further narrow down where to look for populations affected by determining where pooling may occur. Then you can determine where infrastructure is and where populations within the floodplain/low lying areas are. once all information is gathered it can be overlayed to see who was affected and what was damaged.	

Final Exam
RENR 405
25 April 2008

Step 1:
Frame the Problem

Question: How has the use of TBT affected the oyster population and the businesses directly related to the oyster population, and are current regulations sufficient?

Location: Arcachon Bay, France

Information of Interest:

- Where marinas/mooring points are located
- Where oyster grounds are located
- Economic impact: Potentially affected businesses in the oyster industry in the Bay
- Environmental impact:
    - Quantitative:
        - Amount of TBT introduced to the water system
        - Measured or estimated concentration of TBT all over the bay
        - Average oyster population growth in the bay (ideally there is no change) over time before TBT was introduced
        - Average oyster population growth between when TBT was introduced and when regulations/ bans on antifouling paints were enacted
        - Average oyster population growth after regulations were enacted
    - Qualitative:
        - Water quality throughout the bay
        - Effects on oyster reproductive ability

Develop a Conceptual Methodology (see attached flow chart)

1. The oyster population affected
2. Businesses/ industry affected
3. The effects on oyster populations of regulations/ bans on TBT

Problems that could arise:

- There might be a lack of data for oyster populations before scientists began monitoring them for damage due to TBT
- An assumption is made that TBT is the cause of the damage to the oyster population

Step 2: Identify Data Needs

- Counts of oysters—to determine if there are damages to the reproductive cycle of the oysters over time
- Record of oyster sizes—to determine if abnormal sizes correlate to locations thought to be high in TBT
- Population data (?)—to determine the location of businesses related to the oyster industry
- Business records from oyster businesses in bay—to determine if regulations on TBT have fostered a recovery in oyster business profits
- Some form of imagery of the Arcachon Bay area (map, aerial photograph)—to define the boundaries of the given problem
- Oyster grounds locations—to determine if oyster population data (population affected by TBT) correlates to marina/mooring locations
- Infrastructure data (Marina/mooring locations)—to determine where TBT hot spots are

Step 3: Identify Decision Support Tools

- Do any preprocessing necessary for wildlife data (or any other data that needs it).
- Import a map of Arcachon Bay into GIS. Clip the image to only include the water and 2 km inland.

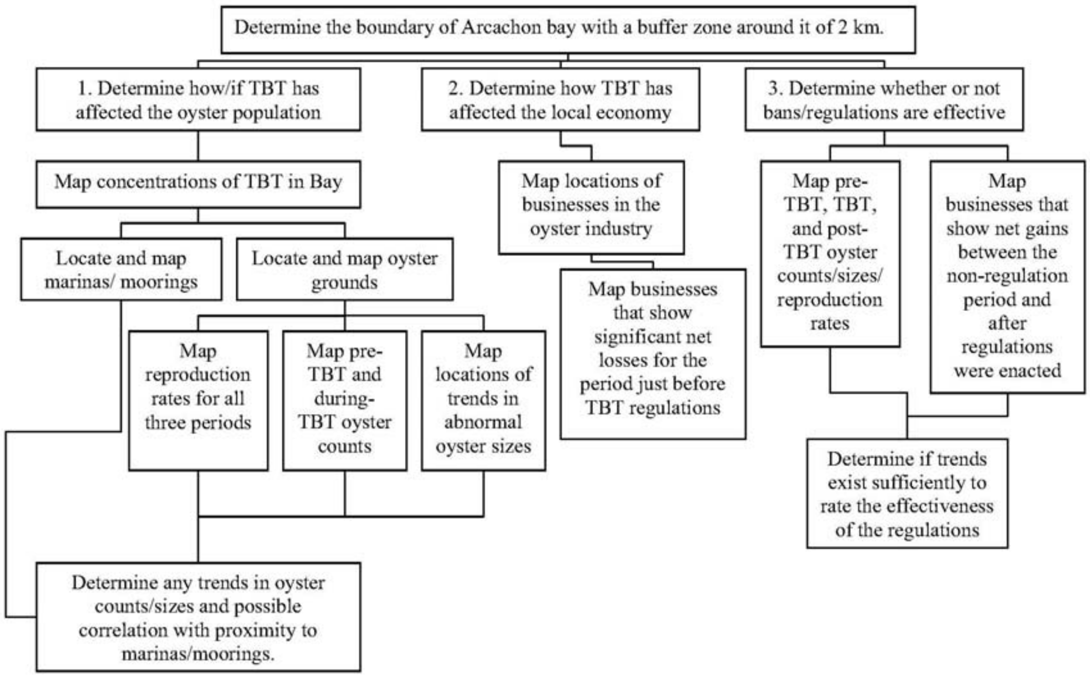
1. The oyster population affected

- Overlay TBT concentration data onto the map and choose a proper color scale

- Overlay (and make semi-transparent) the locations of oyster grounds
- Overlay the points where there are moorings/marinas
- Overlay data that shows the change in oyster count/ reproduction rates/sizes between pre-TBT and the period while TBT was used without regulation. Extract and use only those counts/rates/sizes that are negative/negative/abnormal.
- Determine any spatial trends

2. Businesses/ industry affected
- Use addresses of business involved in the oyster industry and geocode them to plot them on the map
- Select by attributes only those businesses that show significant net losses while antifouling agents were in use

3. The effects on oyster populations of regulations/ bans on TBT
- Repeat instructions for step 2, but instead of selecting businesses by net losses, select businesses that have shown net gains since regulations were enacted.
- Map data showing the changes in oyster sizes/count/reproduction cycle, but select the period after regulation, and extract only those with normal/positive/zero or positive results.


Determine the boundary of Arcachon bay with a buffer zone around it of 2 km.
1. Determine how/if TBT has affected the oyster population
2. Determine how TBT has affected the local economy
3. Determine whether or not bans/regulations are effective
Map concentrations of TBT in Bay
Map locations of businesses in the oyster industry
Map pre-TBT, TBT, and post-TBT oyster counts/sizes/ reproduction rates
Map businesses that show net gains between the non-regulation period and after regulations were enacted
Locate and map marinas/ moorings
Locate and map oyster grounds
Map businesses that show significant net losses for the period just before TBT regulations
Map reproduction rates for all three periods
Map pre-TBT and during-TBT oyster counts
Map locations of trends in abnormal oyster sizes
Determine if trends exist sufficiently to rate the effectiveness of the regulations
Determine any trends in oyster counts/sizes and possible correlation with proximity to marinas/moorings.

Student 2173

MidtermSelect						
ID	Attempt	Fertilizer Plant: Conceptual Methodology (Matching)	Week 2: Fertilizer Plant Methodology Justification	Lake Limestone: Conceptual Methodology (Matching)	Week 2: Lake Limestone Methodology Justification (Paragraph)	Grade
	2	a, d, c, b, e, f	Since the problem lies with the Brazos River and it the amount of sludge disposal, I would first determine tha mount of sludge that would be dumped to see how large of a problem scale we were dealing with. From there I would then determine the contamination level. Comparing that to the history of the river, we can combine that data with the determined flood plain of the river to see which area would be affected the most. From there, overlay the information with the various populations to see who all is at risk if the possible contaminatino level is high. Afterwards, overlay all the information and try to come up with a solution!	d, a, b, e, c, f	One of the first problem solving concepts is to determine the lcoation of the infrastructure. Therefore that would be the first step I would do. Due to the location of the infrastructer, I would then go about determining the amount of water that was lost due to the breakage in the dam. Due to the amount of water lost, the next priority would be the flood plain of the Navasota River to see where the water would accumulate the most. This part coincides with marking any low lying areas because the lower the evevation, the more water and danger of flooding. The populations within the danger zone would be the next concern so that we can warn and evacuate if necessary. From which we overlay all of the data and try to fix the problem.	

TBT: The affect on the Arcachon Bay Oysters

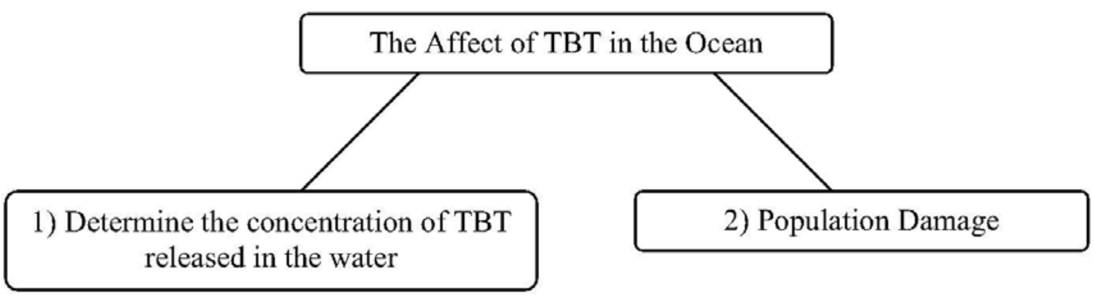
According to the case study "Environmental Problems caused by TBT in France: Assessment, Regulations and Prospects" by Claude Alzieu, there was sea water pollution resulting from tributyltin (TBT) in the Arcachon Bay. Although the problem was solved in the case study, this paper will develop a conceptual methodology into **what are the possible impacts of TBT in the Arcachon Bay.**

Arcachon Bay is a body of water, surrounded in a triangular fashion between the Gironde estuary and the Spanish border. The shoreline perimeter totals to 57 km with the longer line of beach in the south. Due to the shape of the bay, the water circulation must take place through a network of various channels that tend to silt up increasingly. This cause's poor water renewal in the eastern part of the bay despite the high amount of water circulated in the ebb tide. Oyster production in the Arcachon Bay has developed over the last hindered years staring in the 18^{th} century. With production well between 10 to 15000 tons of Crassostrea gigas oysters, any negative affect on the population can hinder the oyster market along with the jobs of many people.

Tributylin or TBT, is a chemical released by antifouling paints used by large sea boats. The antifouling paints a tin-based coating that is used to keep various species (such as algae and barnacles) from attaching themselves and growing onto the boats. By the force of the water, the chemical is released to stop these metallic predators. However, it does more damage than it was originally planned. In 1975 to 1982, there was a severe decrease in oyster production resulting in a decreased reproduction rate. Through various researches, it was concluded that there were anomalies in the calcic growth of the shells along with the complete absence of spatfall caused by the TBT contents in the ocean. This concentration of TIBI proved highly toxic and extremely harmful to the survival and growth of oyster larvae. Although there is a small difference between the toxic level and the normal level of the TBT in the ocean, mortality can happen as early as the second day of exposure.

To solve the issue of the TBT oyster destruction, the French Minister of Environment passed an ordinance restriction the use of antifouling paints on boats under 25m long. This was intended to protect French oyster culture farms and project the marine species.

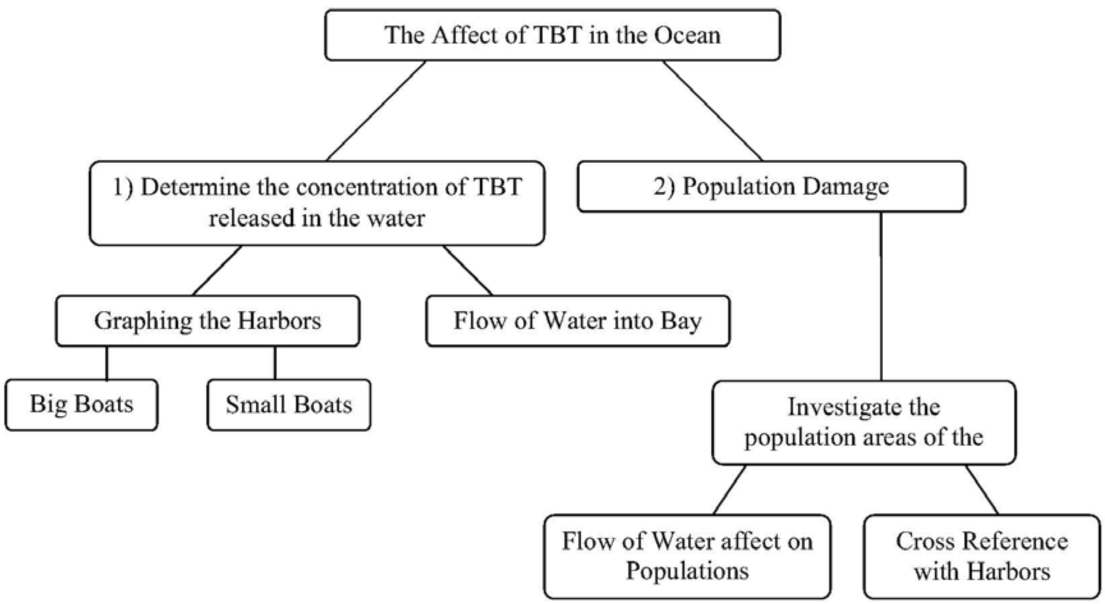
For my conceptual methodology I will begin at the affects of TBT in the ocean. Since TBT is the main source of toxicity in the ocean you can divide that in to the information of interest. For this case study, the information of interest would be the populations affected and the hazardous material. I have developed two methodologies for the report: 1) Determine the amount of TBT released into the water and 2) Determine the affected population or population damage.



TBT: The affect on the Arcachon Bay Oysters

Each of these methodologies have different ways of solving the problem or approaching a way to solve it. Two ways to determine the concentration of TBT released in the water are by graphing where the harbors are within the Acrachon Bay to see where boats dock. With a high number of boats there should be a high concentration of TBT. This can be divided by how many 25m boats there are compared to how many smaller boats (less than 25m) there are. This would give a more precise idea of the source of the concentration. Another way would be to test the separation of the water, down the West and East banks of the bay. Since the flow of water is slim, stagnate water, and therefore higher concentrated TBT water, should exist in the East side. Water is able to flow in and out of the West but not the East.

For the population damages, all you could basically do was investigate the areas where the population was high for the oysters. In the case study, they used an experiment where the control was the oysters living in a control, stable environment and plotted that with the oysters living in the TBT infected water. For this methodology, I decided to try and cross reference the populations living within the harbors to those living in the TBT water. Another population comparison would be to see if the flow of water would have an affect on the density of the population in an area.



Final Exam
RENR 405 4/20/08

TBT: The affect on the Arcachon Bay Oysters

After figuring out a strategy, the data needs are the next part when creating a conceptual methodology. With this type of study, there were two types of data that are beneficial enough to help solve a problem. One type would be the Population Data in which this identifies the density of the oyster population within the Arcachon Bay. Also, location of the infected would be another data set. Are these areas located with in reasonable distances from the ship? Are they scattered out among the bay? All these questions can be answered with the correct amount of accurate data.

These investigations can prove insightful and understanding data to the TBT troubles of the bay. Nevertheless, there are many was to solve this problem; even though the problem has already been solved. Through this methodology, I believe a satisfactory answer can be derived about the affects of TBT in the Arcachon Bay.

APPENDIX D

ATHENTIFICATION OF STUDENTS' SCORES

Spatial Thinking

Level	Example Student Response
1	First the population would need to be located, and then the flood plains should be mapped out. Next, the amount of sludge and it possible concentrations should be evaluated. After getting this information than we can see how the water has moved in the past years and see where the problem exists.
2	First you start out with old data that can help with starting the research. Determining where the populations and flood plain are in the current era will help center in and cut the unwanted data from the historical data. Once the amount of sludge can be determined it will be easier to concentrate on one specific area.
3	You start broad by figuring the whole area of the Brazos River flood plain. Then you use historical data to figure where the water levels would rise to have an affected area. After you have narrowed this down you would determine where there are human and wildlife populations so you can look to see where you have problems. Then you would overlay the information so areas of major concern are apparent. Next you would determine the amount of sludge that has been dumped and finally the concentrations of the sludge so you can determine how big of a problem it will be.
4	In the first step you must determine the amount of contamination so that you can then determine the extent of the other data you need. To narrow down further, determine the floodplain of the region. Narrow further by getting historical water levels (chances are the contamination has not traveled out of the water, so it should only be where the water has been). Sample water to pin point problem areas. Then locate populations within the area you narrowed down. Overlay everything to determine where the problems are (with wildlife and humans).

Content/Subject Knowledge

Level	Example Student Response
1	First the flood plain has to be determined, and then the amount of sludge present and where it would be concentrated has to be determined, and then where the populations that are affected can be determined, then overlaid to find where the problem is.
2	First you start out with old data that can help with starting the research. Determining where the populations and flood plain are in the current era will help center in and cut the unwanted data from the historical data. Once the amount of sludge can be determined it will be easier to concentrate on one specific area.
3	The area of the flood plain and history of river water levels will help to determine how big the problem is. Then, knowing where citizens reside put the endangered into perspective. The amount of sludge that has been dumped will help to determine the next step which is calculating the potential concentrations throughout the river. The final step is to combine all the information and determine where problems exist and where there is a need for immediate action.
4	In the first step you must determine the amount of contamination so that you can then determine the extent of the other data you need. To narrow down further, determine the floodplain of the region. Narrow further by getting historical water levels (chances are the contamination has not traveled out of the water, so it should only be where the water has been). Sample water to pin point problem areas. Then locate populations within the area you narrowed down. Overlay everything to determine where the problems are (with wildlife and humans).

Coherence and Organization

Level	Example Student Response
1	First the population would need to be located, and then the flood plains should be mapped out. Next, the amount of sludge and it possible concentrations should be evaluated. After getting this information than we can see how the water has moved in the past years and see where the problem exists.
2	First you start out with old data that can help with starting the research. Determining where the populations and flood plain are in the current era will help center in and cut the unwanted data from the historical data. Once the amount of sludge can be determined it will be easier to concentrate on one specific area.
3	The first thing that must be considered is where the water could be, and where it has been, so the first two steps would be to find the flood plain, and where the water levels have been over the past 7 years. The next step would be to find where populations live in the area. Now that all affected areas are found, the amounts of contaminate need to be decided, so the first thing would be to find how much of the sludge has been dumped, and then the concentrations throughout the river. Finally, all information should be combined to find where the problem exists.
4	In the first step you must determine the amount of contamination so that you can then determine the extent of the other data you need. To narrow down further, determine the floodplain of the region. Narrow further by getting historical water levels (chances are the contamination has not traveled out of the water, so it should only be where the water has been). Sample water to pin point problem areas. Then locate populations within the area you narrowed down. Overlay everything to determine where the problems are (with wildlife and humans).

APPENDIX E

IRB APPROVAL FORM

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU
College Station, TX 77843-1186
1500 Research Parkway, Suite B-150

979.458.1467
FAX 979.862.3176
http://researchcompliance.tamu.edu

Institutional Biosafety Committee | Institutional Animal Care and Use Committee | Institutional Review Board

DATE: 01-Feb-2008

MEMORANDUM

TO: BALL, KENDALL C
77843-3578

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Initial Review

Protocol Number:	2008-0037
Title:	Study of Course Curiculum of RENR GIS Enviromental Problem Solving
Review Category:	Exempt from IRB Review

The Institutional Review Board (IRB) has determined that the referenced protocol application meets the criteria for exemption and no further review is required. However, any amendment or modification to the protocol must be reported to the IRB and reviewed before being implemented to ensure the protocol still meets the criteria for exemption.

This determination was based on the following Code of Federal Regulations:
(http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm)

45 CFR 46.101(b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (a) research on regular and special education instructional strategies, or (b) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Provisions:

This electronic document provides notification of the review results by the Institutional Review Board.

VITA

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