Enhancing GIS Education with Student-Created Labs and a Peer Reference Manual

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ABSTRACT

Typically, students from a wide variety of academic majors and backgrounds enroll in introductory Geographic Information System (GIS) courses. In these classes, students learn the basic analytical skills and geographic science in order to appropriately use a GIS, while also learning the mechanics of a particular GIS program. In order to engage the class more fully in the learning process, we ask each student to select a topic that captures his/her interest (for example their major, hobbies, sports, or other interests) and to create a GIS lab around it. Also, we ask our students to solve some GIS questions using resources other than the instructor(s). As students in the GIS classes realize their work requires a skill not fully covered in their previous course work, they need to learn the steps to accomplish the task(s). After discovering the solution, the students write the procedures, which then become incorporated into a student-generated GIS reference manual. This manual acts as a resource to all students and faculty using GIS. These projects require the students to engage problem-solving and communication skills in addition to their GIS abilities. We have found that in generating and executing these exercises they cover a variety of pedagogical goals.

INTRODUCTION

Many college campuses across the United States now offer introductory GIS courses, but unlike most college courses, a variety of departments teach these basic GIS classes. A cursory look at university GIS classes reveals offerings from geoscience, business, environmental science, sociology, and forestry departments. The interdisciplinary nature of GIS means that these courses attract a diverse student population (for example, Dramowicz et al., 1993). As instructors, we continually search for methods to maintain our students' interests in the topic as well as to assess student competency of the skills we teach. Since GIS is a rapidly evolving and widely used field, GIS instructors need to continually modify and update the materials they teach (Keating and Franz, 1999). Technology-based courses may need significant alterations after only two or three years compared to more than five years for a non-technology based class (Agnew, 2001). Incorporating a component of the class that motivates and engages students, as well as a component that is easily translatable regardless of the technology, prevents the instructor from constantly needing to redesign class assignments. Agnew (2001) mentions promoting greater understanding, developing skills, fostering active learning, and motivating and enthusing as reasons for changing curriculums. In our case, as two new instructors, we faced restructuring Baylor's Introduction to Remote Sensing and GIS course that split into two separate courses (Introduction to GIS and Principles of Remote Sensing). Our pedagogical techniques began as personal innovations, but we continually discover much support for our ideas in the higher education literature.

The goal of an introductory GIS class is to teach students GIS concepts while allowing them to gain practical hands-on experience with specific software packages (Deadman et al., 2000). Our design of student-created labs uses that paradigm and adds unique benefits for students and instructors. We also assign a final group project that encourages the use of real-world problems to solve as a team. This assignment requires the students to work together to learn and determine the steps to solve their problems, which follows the problem-based learning theory Svinicki (1999) discusses. During their project work, we encourage the introductory GIS students to write the steps of newly discovered skills or methods and to add these procedures to the GIS lab's peer reference manual.

STRUCTURE OF OUR INTRODUCTORY GIS CLASS

Our class consists of approximately three hours of lecture and two hours of lab per week. Early in the semester, we inform the students that they will design their own lab and will also work on a small final group project. However, the laboratory portion of our introductory GIS course begins with basic exercises to familiarize the students with the software and its capabilities. For example, we use the ESRI "Getting to Know" books and other similar lessons. Students new to GIS need these exercises; however, we notice that students tend to experience difficulty in trying to work through exercises lacking detailed procedures. Other instructors suggest (Kilpinen, 2001; Russell et al., 2001) following the typical tutorial GIS exercises with more intuitive ones that require the students to incorporate problem-solving skills with their GIS skills to answer particular questions, some of which may contain more than one correct solution.

To further develop the students' GIS skills, we want to incorporate a project into the curriculum that motivates the students to become self-learners and to retain learned skills. Since students today profess the desire to receive good grades, but not necessarily learn the material, instructors seek methods to motivate actual learning (Picard, 1999; Theall, 1999). A large GIS project, especially an individual one, can be daunting to anyone new to the subject (Kilpinen, 2001). To bridge the gap between step-by-step labs and a GIS project, the students complete instructor-created exercises which provide fewer and fewer elementary steps, thus leading the students to rely on skills previously learned.

Because the students possess a variety of knowledge bases, going in depth on one topic is often not interesting to everyone. Through lectures and basic labs, the students learn that GIS is an interdisciplinary tool. They realize how to apply GIS to study plate tectonics, climate patterns, locating a new business, etc. But to maintain

Lab Title	Main Topic	Lab Creator's Major
Conservation Strategies Using GIS	Preserving appropriate land for owls	Biology
Hewitt, Texas-2000 Census Query	Using Census data to study town demographics	Physical Geography
Importing Remotely Sensed Data and Selecting Associated Watershed Features	Data compilation & querying for a watershed study	Biology
Income Levels in Texas Counties	Effects of NAFTA in Texas along I-35	Economics/Geography
Location Proposal for AIDS Awareness Program	Determining optimal locations for AIDS office in Africa	Geology
Mapping Destruction of Central Texas Tornados	Understanding tornado paths & destruction levels	Earth Science
Preliminary Flood Report for June 5-9, 2001 in the San Jacinto Basin	Plotting data from USGS stream gages & mapping flood info	Environmental Studies/Earth Science
Protecting Texas' Water Supply from Radioactive Contamination	Locating radioactive waste sites & their proximity to population centers	Journalism
Site Location Analysis Lab for ArcView GIS	Locating a new grocery store in Waco	Human Geography
Spheres of Influence: U.S. War on State-Sponsored Terrorism	Mapping U.S. military bases and terrorist regions	Political Science
State Parks of Brazoria County, Texas	Park information and hot links	Secondary Education
Waco Crime Lab	Determining various local crime areas	Physical Geography

Table 1. Sample of some of the student-designed labs in an introductory GIS course.

each student's interest, we require the students to select subjects that interest them and develop introductory GIS labs involving those topics. While this assignment enhances the students' GIS skills, it allows them to personalize their studies, which our students respond to positively. One student commented that she enjoyed writing her lab about her research on fishing and fishermen's beliefs, which also helped her add another component to her senior research project. The assignment also expands the class content since it tends to be difficult for instructors to select or create exercises that cover all the students' interests. At the end of this exercise, the students then further learn how to apply GIS skills to other fields by listening to their classmates present the labs they develop.

STUDENT-CREATED LABS

One cognitive model strategy includes determining the learner's prior knowledge before starting instruction and then relating that knowledge to the course (Alexander et al., 1994; Ausubel et al., 1978). But this technique proves difficult in our class because no prerequisite geoscience class exists to provide a common base to build upon, and our enrollment consists of students from many different majors and education levels (i.e. upperclassmen and graduate students). Edelson and Gordin (1998) state that utilizing skills familiar to students in introducing new skills and concepts is successful. The known skills provide a basis or bridge to learn new ones. In the aforementioned study, the students drew representations of current climate views as a starting point to understand how scientists visualize and interpret global climate changes. Following this idea, the instructor activates the learners' prior associations by asking them to think about what they already know and using examples within the range of the learners' experiences (Svinicki, 1999). Thus, our students select familiar topics to combine with their newly acquired GIS skills. This merging of personal interest and class work offers a springboard for the students to expand their GIS skills, as well as providing a new approach to study something familiar. This assignment helps the instructor to know some of the learners' prior backgrounds and present abilities. It provides the instructor the opportunity to learn more about the individual students, current topics of concern to them, and how they relate to the world today. This assignment also makes the subject of GIS valuable and fun for the students by giving them ownership of the material. When students incorporate their prior knowledge in learning GIS, it enhances their ability to retain the newly learned skills by building relationships between old and new information (Svinicki, 1999).

For the student-created labs, each student needs to select a topic of interest, whether it be in his/her major, a hobby, sport, etc. The diversity of the students in the course results in a wide variety of topical and technical projects (Table 1). Then they need to brainstorm how GIS can be used in their selected fields. Some find this step relatively simple, while others need assistance to see how to apply GIS in their fields or how to explain more about their fields using GIS. The students also select an audience and experience level for their labs and the GIS skills that the labs cover. By this point most students seem to formulate general designs for their labs.

Following the outline (Figure 1) we provide the students, the assignment includes writing an introduction, a scenario with objectives, the skills and concepts covered, procedures, and questions to be answered by the individual completing the exercise. The student lab creator also provides an instructor copy with answers, examples, and hints, as well as the data used in the lab and the corresponding metadata. Since students are responsible for collecting or creating the data they need, they utilize their data gathering and modifying skills, such as importing, reprojecting, deleting extraneous information, and possibly adding more

Your Title

Introduction:
Background/general information on the field you have selected.

Scenario:
Setup for the lab, desired results of doing this lab, end products, etc.

Skills/Concepts Covered:
Student will learn...

Materials:
Whatever is needed to complete this lab (such as data)

Procedures:
Steps to complete the lab, including any questions to answer (or you can put the questions at the end) and images, layouts, tables, etc. to make. You can write the procedures as 1., 2., 3., ... or Task A: 1., 2., ... Task B: 1., 2., ... You can include icon images or procedure windows for clarity.

Final Product(s):
List the work the students are to turn in to the TA. For example, questions to answer, a write-up, layout(s), table(s), etc.

References:

Metadata:
See attached metadata file called...

Level of Difficulty:
Lab designed for someone unfamiliar with ArcView
Lab designed as a capstone to an intro course
Lab designed to refresh someone's ArcView skills

Lab Creator:
Name:*John Doe*
Degree Program:*BS*
Major:*Geology (hydrology)*
Graduation:*Spring 2003*

Lab Creation Date: Spring 2002

Additional Comments:

Figure 1. Handout given to students when assigned the lab creation project. This outline provides the students with the basic structure to follow as they design their lab.

attributes. Throughout this process the students identify the knowledge and skills they need to create their lab, which conforms with Sheppard and Cosgriff's (1998) discussion of problem-based learning.

ASSESSMENT STRATEGIES

Providing students with clear objectives and guidelines makes the project less threatening to them and assessment easier for the instructor because the objectives are clearly stated in advance (Svinicki, 1999). For this reason, we hand out evaluation forms (Figure 2) early in the process and leave a notebook in the computer lab of example projects from previous semesters. The students prefer to receive the evaluation forms at the beginning of the project, so they can better understand what we expect of them. One student questioned whether our like or dislike of the chosen topic influenced the grading. The evaluation form shows the objectivity in the grading and reminds the students of the various aspects of the project.

The first time we taught the class, we noticed some students waiting to the last minute to complete their labs. In an effort to improve the quality of all the

LAB PROJECT PRESENTATION EVALUATION FORM

Name of Speaker

Voice (volume, speed, clarity)	________	(Points: 0-15)
Language (pronunciation, grammar, adequate explanation of technical terms)	________	(Points: 0-15)
Physical Manner (appearance, gestures, poise, movement)	________	(Points: 0-15)
Quality of aids (slides, overlays, handouts; neat, helpful, easy to understand)	________	(Points: 0-20)
Effectiveness (maintain interest, material clearly presented, adequately covered the topic)	________	(Points: 0-20)
Speech organization (introduction, body, conclusion, progression of ideas, from TA viewpoint)	________	(Points: 0-15)
Total	________	

LAB PROJECT EVALUATION FORM

Name

Concept/Scenario	________	(Points: 0-10)
Procedures (difficulty, clarity)	________	(Points: 0-15)
Grammar, writing	________	(Points: 0-10)
Format	________	(Points: 0-5)
End products (questions, maps)	________	(Points: 0-15)
TA version - answer key, examples	________	(Points: 0-15)
Metadata	________	(Points: 0-10)
Does the lab work	________	(Points: 0-5)
Overall impression (response to feedback, originality, attitude)	________	(Points: 0-15)
Total	________	

Figure 2. Grading forms provided to the students and then used in the evaluation process.

student-created labs and to catch problems with the labs earlier, we now require the students periodically to turn in portions of their project. For example, about midway through the semester the students turn in their topics, later their introductions and scenarios, then the concepts covered and data requirements, followed by the procedures, and then the complete projects. These intermediate deadlines keep the students on track and allow us to know how they are progressing. The students also know how well they are completing the assignment. At each of these steps the instructor and teaching assistant provide comments to individual students. Recurrent problems and examples of good work are used to help the entire class. These mutually beneficial periodic assessments and feedback encourage students to succeed by showing the instructor's interest and exposing errors early in the process (Angelo and Cross, 1993; Loacker, 1988). A teaching assistant can help review the students' materials. However, we still encourage some faculty involvement, so you know your students' interests and abilities and to catch some of the nuances in the procedures that the teaching assistant misses. As noted by Bailey (2002), instructor enthusiasm and awareness of student work increases student interest and motivation in his/her work.

This dynamic process of assessment also helps the students discover their abilities and see their improvements (Loacker, 1988). The cyclic nature of feedback allows for the students to make improvements and modifications along the way. Reviewing the projects

Topic	Title
Address Matching	Creating Shapefiles by Address Matching
AutoCAD Files	Using AutoCAD Files in ArcView
Census Data	Downloading Census Data for Use in ArcView GIS
Creating TINs	Creating TIN Data Using 3D Analyst for Elevation Values from the Texas Digital Climate Atlas
Didger Digitizing	Using the Digitizing Tablet
DOQ Data	Downloading and Displaying DOQs in ArcView
ESRI Files	Project and Data Management in ArcView 3.3
Georeferencing	Georeferencing a JPEG Image
GPS Data 1	GPS to GIS through Excel
GPS Data 2	How to Transfer Data from Garmin GPS Units to ArcView GIS 3.x Using MapSource
Maps from AV to AI	Porting Maps from ArcView to Adobe Illustrator
Network Analyst	Network Analyst Example: Making an Itinerary for Tourists
NeuraMap	Getting Started with Neuralog (semi-automatic digitizing)
Using Text	Text Modifications in ArcView
Watershed Data Collection	Where to Collect and How to Import Spatial Data for Watersheds

Table 2. Sample of some of the student-created reference manual entries.

only after completion leaves the students little incentive to improve or learn from their mistakes and results in poorer quality work. Our method of periodic assessment helps them to learn better and to improve their skills as they go, and they begin to see repetitive assessment as a necessary part of the learning process (Loacker, 1988). The following are examples of the benefits of this teaching style. One student feels his lab is not complex enough because of the simplicity of the actual GIS skills. We encourage him to pursue his concept and to create a well-developed scenario and application. Through the continued progression of the assignment, we can suggest any modifications as needed. Conversely, another student thinks her idea is too complex and that she might not be able to complete her desired lab. In monitoring her progress, we will help her simplify aspects of the lab and provide additional assistance through more complex portions of her project. We mention these examples to the entire class to allay any similar unvoiced troubles. Discussing questions and concerns such as these with the entire class prove beneficial since others are probably experiencing similar difficulties or confusions (Bailey, 2000). We reinforce the idea that the labs will have different levels of GIS skill difficulty. Overall, the process tells us what the students learn, how they progress, and if we need to modify our teaching.

The diversity of our students also means that some require additional assistance while others forge ahead with little need for assistance. The lab creation assignment provides the flexibility for more advanced students to further develop their GIS skills and for students experiencing problems in class to receive more assistance. In the end, the students take control of their learning by possessing the freedom to work at their own paces and level of abilities. This assignment allows the instructors to adapt the instruction to individual needs.

Toward the end of the semester, the instructor reviews the nearly complete projects; the students then exchange labs and work through a classmate's exercise to provide additional feedback during a scheduled lab period. This step corrects any remaining logistical errors and provides an estimate of the completion time the exercise requires. Following peer review, the lab creator receives his/her lab with comments for final modifications. Each student then presents his/her exercise to the entire class by means of a digital slide show, which shows the class the diversity of their colleagues' interests and the various applications of GIS. The course instructor, lab instructor, and classmates evaluate these presentations using the first section of the form in Figure 2. Assessment from their peers and the instructors encourages the students to become more involved in their own learning process and that of their classmates (Loacker, 1988). We require the presentations because we believe the ability to present material is an important aspect many students leave college lacking. Many students need improvement on their speaking skills and need the opportunity to increase their confidence in presenting their work. Thus, we assign short presentations throughout the semester culminating in the presentations of their lab creation projects and their final group projects. Upon completion of the assignment, the final products are then stored on the GIS server with access provided to all the students. Some burn CD-ROMs of the material for possible use if they become GIS teaching assistants. Secondary education teachers also make copies for use in their future classrooms.

STUDENT-CREATED LAB EXAMPLES

One student's inspiration for her lab came from the remote sensing class she was concurrently enrolled in. She needed to complete a remote sensing project on landuse changes over time associated with dam construction. She wanted to combine some GIS layers with the remotely sensed images, so she imported the images and hydrologic data into the GIS. Then she used her skills to cull and query the hydrologic data she would need for her remote sensing project. She could then

How to Transfer Data from Garmin GPS Units to ArcView 3.x Using MapSource
Author: GIS Classmates - Spring 2002

1. Connect the Garmin GPS unit to the COM port using the transfer cable (cable is plugged into the Instructor computer in the lab)
2. Open *MapSource* (Start ? Programs ? MapSource)
3. From the **File** menu choose <Open from Device>
   - a.What to open: if you just want waypoints, make sure just waypoints is checked.
   - b.Click <Serial Connection Settings> to make sure the computer recognizes the GPS unit is connected. (Note: MAKE SURE YOUR GPS UNIT IS ON! On the Interface page of the GPS, make sure the serial data format is set to GARMIN.)
   - c.Click <Auto Detect>. This allows the computer to automatically find the GPS unit.
   - d.Click if auto detect is successful.
   - e.Click to close out of the **Serial Connection Settings** page.
   - f.Click <Open> on the **Open from Device** page.
   - g.A box should appear that shows the transfer taking place. The GPS unit will not show anything on its screen.
   - h.Click if the **Open Complete** dialog appears.
4. Your waypoints should now appear on the left hand side of the screen. This program automatically extracts all waypoints held in the GPS unit. If there are any unwanted points, simply highlight them and click the delete button (it's an X at the top of the screen.)
5. Now the data has to be put in the correct format for ArcView. From the **Edit** menu, choose <Preferences>.
   - a.Position: Position format-Lat/Lon hddd.ddddd^{o}
     Map datum-Choose what your map is in for ArcView
   - b.Click to exit preferences
6. From the **File** menu, choose <Export> — You cannot simply do a save as because the data will not save as the correct type. The Save As prompt will appear ? choose your folder. Name the file and set the save type as: text (tab delimited)(*.txt). Click <Save>.
7. Minimize *MapSource*. It's now time to work with ArcView

8. Open *ArcView* with a new view, but do not add any themes

Figure 3. A portion of an entry into the student-generated reference manual. A group of students worked together to write procedures to retrieve data from a GPS unit and import that data into a GIS.

export the data to use in the remote sensing software package. She incorporated this learning process into her class assignment by creating a scenario where the reader modified data files and generated some simple statistics on the dams.

Many students also incorporate enthusiasm and humor into their labs. One of our favorites is a lab where the scenario asks the participant to pretend to be superman (or woman), who gets laid-off from his job of saving the world. Now, he needs to fly aerial photography for the local county and make some decisions about river channel conditions and bridge locations. Other topics involve development of a local wetland, research in Costa Rica, and sea turtle habitats (also see Table 1).

STUDENT-GENERATED REFERENCE MANUAL

During their lab creation and other GIS work, the students often want to accomplish some tasks or analyses that their basic GIS experiences do not fully cover. They will often encounter this situation outside the realm of academia. Therefore instead of providing the students the answers or procedures, we challenge them to discover the solution with as little instructor input as possible. We encourage the students to use software manuals, colleagues, and the Internet to find a solution. Generally, students resolve the majority of their questions by working through the process individually or with classmates. Usually the instructor's assistance tends to be in helping them debug minor aspects of their procedures. We ask the students to take notes during their problem-solving process. These notes can then easily be translated into a format for others to use. Then we compile these student-written techniques into a reference manual that remains in the computer lab, so present and future students with similar questions can use the techniques provided by their peers (Table 2). Frequently, we include portions of the student-created lab assignments in the peer reference manual. The student-generated procedures benefit the students by acting as an additional reference source in the form of a lab handbook, which is especially useful when students work at night and an instructor is not available. The manual also helps the instructor by allowing us to refer students to it rather than needing to explain or teach the process to everyone that experiences the same dilemma. Often we find that students misunderstand directions written by "GIS experts". Establishing a manual in the lab written "by students, for students" often increases the probability of their comprehension. This technique allows students to access an array of material to complement their learning. We received such positive feedback from the students who submitted entries to the reference manual and from those using the manual that we require students in the subsequent GIS course (Applied GIS) to make at least one submission.

Most jobs, whether in the GIS field or not, will require some form of problem solving. The trend is to add more problem solving to introductory science courses since science and the real world require problem solving (Bailey, 2000; Dupre and Evans, 2000). Additionally, some students lack well-developed problem-solving abilities (Dupre and Evans, 2000; Guertin, 2000), and encouraging them to try to discover the solution on their own improves these skills. They typically experience greater difficulty when they study outside of their major field; however, some simply need ideas for problem-solving strategies (Svinicki, 1999). Throughout the semester we discuss how and where to find solutions to questions and the processes involved when a problem arises. By providing demonstrations and examples of various ways to approach and tackle problems, the instructor shows students that many techniques or methods can be used to solve the same problem. Martin and Arendale (1994) refer to this as supplemental instruction. Forcing the students to work through the task themselves provides them with the confidence and skills to work through similar situations on their own in the future (Brown et al., 1991; Bailey, 2000). These exercises also force students to effectively present and communicate their knowledge to someone with little experience in their field or with a particular technique. Thus, they become reciprocal teachers and begin to see and appreciate how much they have learned.

EXAMPLES OF STUDENT-CREATED REFERENCES

In one group project, the students compiled various GIS layers on a city park. As part of their work, they took a GPS unit to the park and mapped the various trails. After collecting the field points, they needed to transfer the data from the GPS unit to the GIS software. The process required the use of multiple software packages and additional hardware connections. Thus, the students needed to refer to various manuals to accomplish the translation from GPS unit to GIS. After determining the correct process, the students took their newfound skill and compiled their procedural notes into an easily understandable format, passed that knowledge on to their teammates, and added their document to the lab reference manual (Figure 3). During this process, the students gained familiarity and skills associated with word processing, spreadsheet, GIS, and GPS, software and the Internet, thereby acquiring important transferable skills.

Another student needed to digitize a map for part of her group project. Since she had never used that digitizer or software, she read through the manuals to discover the process. She then took what she learned and wrote down the steps in the proper order from digitizing to exporting her work in an appropriate format. Other students have since used her procedures to digitize data. These students found the peer instructions easier and more straightforward to use than the software manual. The students seem to find instructions written by their peers less daunting than manuals from a software company.

Some reference entries are less involved than these. For example, one student discovered some helpful techniques to exporting a map from one program and importing it into another, so he added these hints to the reference manual. We utilize his instructions in another class, which results in fewer missteps by the students because they benefit from their peer's techniques.

PEDAGOGICAL BENEFITS

Many pedagogical benefits exist to the process of "creating your own lab" and self-discovery of procedural solutions by students in a GIS class. Picard (1999) states that science students need to think through and resolve problems on their own. Often, getting students to think problems out for themselves is the most challenging aspect of teaching in an applied field like GIS. As educators who are constantly learning ourselves, we realize that education usually entails reorganizing our thinking and understanding, but students often lack this skill (Svinicki, 1999). We want our students to take charge of their learning rather than act as passive learners. Brown (1978) refers to this concept as "thinking about thinking" or metacognition. To facilitate this, the instructor can activate the learner's prior associations by asking them to think about what they already know and using examples that are within their experiences (Svinicki, 1999; Edelson and Gordin, 1998). These activities also provide an opportunity for learners to receive feedback on their understanding (Angelo and Cross, 1993) and require active learner involvement at many steps in the process (Svinicki, 1999; Sheppard and Cosgriff, 1998). As one can see, this course follows a very learner-centered, learner-directed interpretation of learning and motivation as Svinicki (1999) discusses these theories. This approach also covers the Seven Principles for Good Practice in Undergraduate Education (Chickering and Gamson, 1987) which includes: encouraging student-faculty contact (e.g. assistance with lab procedures, ideas, and logistics), encouraging cooperation among students (e.g. we recommend the students ask their colleagues for assistance before asking an instructor and students using procedures written by their peers), encouraging active learning and feedback (e.g. periodic instructor and peer assessment processes), and respecting diverse talents and ways of learning (e.g. incorporating personal interests into the class assignment).

SUMMARY

Student-created labs capture the imaginations and motivations of students simultaneously by allowing them to apply their interests to GIS course work and learn new skills to use within their fields. This project offers a step beyond traditional assignments because it allows students to apply their previous skills rather than simply follow a step-by-step lab exercise or work with a topic of little interest to them. Both the lab creation and reference generation projects help students with organizational skills because they need to generate instructions that another person can follow. Through these assignments, students learn many mechanisms for improving learning and how to activate self-learning techniques.

The basic formula of student-created labs is: knowledge and skill + interest area + analysis and problem solving = lab. The student-generated technical procedures apply a similar formula, usually substituting current need for interest area. The student products provide material for future GIS and other related geoscience classes and peer assistance in the form of the lab reference manual. At the end of the course, the students feel confident in their abilities to solve basic GIS problems and explain the methodology to others. The creation of the reference manual and encouraging the students to work through problems themselves further enhances their confidence. The skills they acquire encourage them to think about different methods to use in problem solving and provide them a base for working on interdisciplinary projects whether it is in their course work or in a work place environment.

This teaching style also allows for flexibility in the mode of instructional delivery (Deadman et al., 2000). We can give students experiencing greater difficulties more individual attention and advanced students the freedom to explore beyond the traditional course material, and this exercise easily transforms with the release of new GIS software versions. We think we have designed a workable set of pedagogical goals for the Introductory GIS course allowing for the students to learn by doing (Deadman et al., 2000) and by providing them the latitude for creativity and self-learning.

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