Using Model-Centered Instruction to Introduce GIS in Teacher Preparation Programs

Judy Lambert

Department of Curriculum & Instruction, Judith Herb College of Education, The University of Toledo, 2801 West Bancroft St., Mail Stop 106, GH 2000G, Toledo, OH 43606, judy.lambert@utoledo.edu

ABSTRACT

The University of Toledo offered an introductory course in Geographic Information Systems (GIS) for teachers, the first of its kind taught in the College of Education. The course objectives sought to increase teachers' GIS skills, knowledge of geographic inquiry, application of the inquiry process to solving problems related to K-12 curricula, and ability to locate useful GIS resources. The course that met for four hours a day for two weeks, included seven graduate-level teachers in the areas of art, physical education, science, and math. Model-centered instruction focused on a geographic inquiry model served as a framework for course instruction, class activities, homework, and project designs. Final projects demonstrated that teachers learned to see relationships between geography and their respective disciplines, apply an inquiry model to solving problems, and think critically about geographic information when provided with steps from an established model. Course outcomes lend some evidence that even a very short course can be a very effective means of introducing GIS in a teacher education program.

INTRODUCTION

Geospatial technologies such as a geographic information system are becoming increasingly important in our everyday lives. GIS is a collection of hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (Environmental Systems Research Institute [ESRI], 2007). The U.S. Department of Labor (2004) named geospatial technologies as a field with the greatest demand for 21st century decision-making. As these tools become critical in solving everyday problems referenced to geographical locations, the ability to think spatially is an increasingly important skill for students. In their recent book, "Learning to Think Spatially," the National Research Council (NRC) (2006) called for the focused and systematic attention of scientists and educators to understand the process of spatial thinking, develop systems to support the process, and ensure that all students have the opportunity to learn about spatial thinking. NRC contends that when GIS is integrated in a standards-based school curriculum, it is one of the most effective tools that can foster the development of spatial thinking. According to NRC (2006), integration of spatial thinking and GIS across school subjects in K-12 experiences is necessary if students are to understand the spatial dimensions of human experience and transfer this kind of thinking from one domain to another. They recommend that Colleges of Education establish guidelines for pre- and in-service teacher training programs and develop a model standards-based curriculum for teaching about GIS. Recommendations such as these are not without challenges.

In competitive times when many universities face declines in student enrollment and reductions in program requirements with fewer elective choices, it is unlikely that the integration of geospatial technologies will be seen as a critical concern. It may be more expeditious for faculty to find creative avenues to infuse spatial thinking and related technologies within their present circumstances. This article considers the challenges of introducing GIS to educators and how these challenges were met through designing a GIS summer course for graduate students in the College of Education. A student's final project will illustrate important learning outcomes. Conclusions and suggestions are made for others who might consider a similar undertaking.

CHALLENGES

K-12 teachers already face the overwhelming demands of assessment accountability, increased diversity in students, and an already burdened curriculum. Similarly, university faculty have the pressures of time constraints, lack of administrative support or incentives, and charge to integrate basic technologies in their coursework without systematic training. While we think that technology will enhance learning, most faculty do not have sufficient time or training to integrate these skills into their course instruction. Evidence suggests that Colleges of Education have not yet successfully integrated technology in their teacher education programs (Kay, 2006) and as a result, new teachers are unprepared to integrate basic technologies in their classrooms (CEO Forum on Education and Technology, 2000). Furthermore, one might think today's net generation is more technologically proficient but this proficiency is limited to technologies such as checking instant messages, downloading music, and conversing in social networking spaces on the Internet (Lorenzo and Dziuban, 2006; Oblinger and Hawkins, 2006). When it comes to using a variety of technologies such as those in the geospatial field, students are far less prepared and need much more experience in using technology as problem-solving tools.

Like technology, inquiry-based learning, which is at the center of good science teaching (NRC, 2000) and geography, has met with teacher resistance. Most teachers still employ direct instruction, not inquiry (AAAS, 1994; McEwin et al., 2003; NRC, 1996) even though it has been found to promote student motivation and connect curricula to issues that interest students or affect them directly, especially for minority urban students (Patrick et al., 2000). Inquiry approaches are particularly important to the study of geography and are even more essential now that GIS is fundamentally used to answer questions and make decisions in government agencies, industry and organizations, and academic

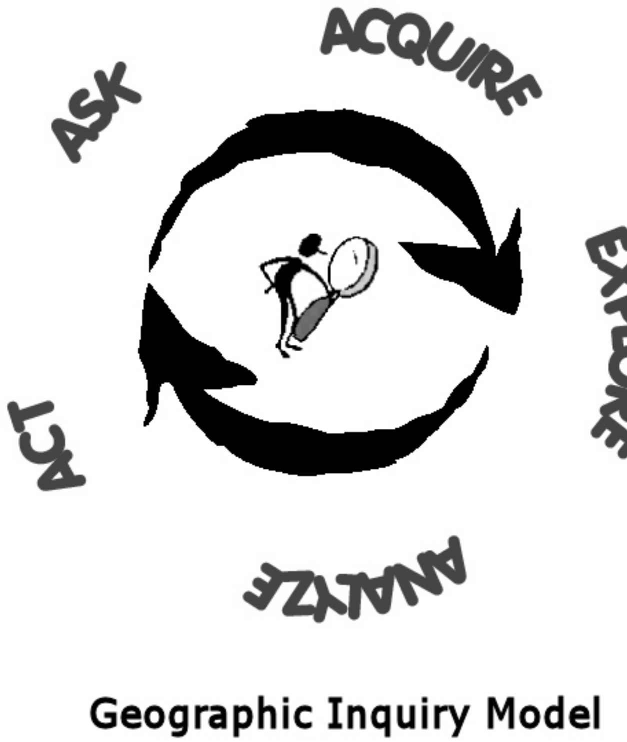


Figure 1. Geographic inquiry model.

institutions. Yet, many educators have long equated geography as an isolated discipline whose purpose is solely to name places on a map. They are not fully aware of geography's potential to cross disciplinary boundaries and address many of the critical issues facing today's society. Limitations in understanding of inquiry and geography may prevent teachers from integrating geospatial tools to let students visualize problems from a geographic perspective (i.e., location, interrelationships, and spatial representation). While the number of GIS-using educators is growing, teachers in one study who had adopted GIS were already experienced in technology and inquiry instructional approaches (Kerski, 2006). Even if we eliminate the barriers of technology and inquiry, one more issue must be resolved for teachers to integrate GIS effectively. They must know how to approach discipline-specific inquiry from a geographic perspective.

It is difficult to understand how another human perceives the world and mentally processes thoughts to interact with the world. A cognitive approach for understanding how another thinks is referred to as a mental model or mental map (Craik, 1943; Johnson-Laird, 1983). A mental model is derived from what an individual already knows about related concepts. Johnson-Laird (1983) has argued that spatial reasoning, an integral element of a geographer's thinking, is based on the construction and manipulation of mental models in memory. Model-centered instruction must promote the development of a cognitive structure (i.e., schema) that is most consistent with the desired learned performance (Merrill, 2001). In other words, if we desire teachers to conduct inquiry in a similar fashion as geographers, then instruction must promote this form of inquiry. By using model-centered instruction and supportive learning environments, individuals can be influenced to construct a particular mental model, visualize complex phenomena, and understand investigative processes in a particular domain (Seel, 2003). Mental model development as an instructional approach has shown positive results when learning about physics, inferential statistics, foreign language, and astronomy (Butcher, 2006; Hong, 1992; Kaplan, 2001; Merrill, 2001; Taylor et al., 2003).

Instructional strategies that will help others acquire a mental model include problem solving activities that increase incrementally in complexity, demonstrations, guided discovery, and plenty of practice in solving similar problems (Merrill, 2001). Other strategies are "think aloud" activities in which the steps of problem solving are verbalized (Lucas and Ball, 2005) and using diagrams to enable visualization of a process (Seel, 2003). It was hoped that by using an established geographic inquiry model in course design that teachers would have tools they need to use GIS, integrate geography in their particular disciplines, and learn to apply a geographic perspective to solving problems.

GIS COURSE DESIGN

To address the need for GIS integration in teacher education (NRC, 2006), a graduate-level GIS course was offered at a Midwestern university in the summer of 2006. Using a model-centered approach (Merrill, 2001), the course was designed around a geographic inquiry model incorporating suggested strategies for model-centered instruction (Lucas and Ball, 2005; Merrill, 2001; Seel, 2003). It was intended that by using this model, teachers would learn degree of geographic thinking. Focus of the course was to provide teachers with basic GIS skills and ability to integrate these skills in their classroom curriculum.

Context - The GIS course was designed specifically for educators with no prior experience using GIS. All but one of the students were practicing teachers; the group was comprised of one full time doctoral student and six Master's level teachers with undergraduate degrees in various educational disciplines and grade levels. Two teachers were licensed in high school math, two in high school science, one in middle school science, one in physical education, and one in art education. Only one of the teachers had previous minimal experience using GIS software. Teachers attended the three-credit hour course four hours a day for two weeks in the college's computer lab. They were introduced to several free educational versions of GIS software (ArcView & ArcVoyager), but ArcGIS (version 9) was used for all course instruction, class activities, and project completion. Although no GIS homework was required outside of class, one text, Mapping Our World offered teachers a yearly license of ArcGIS (v. 9) (ESRI, 2006) software for classroom use. Required textbooks included:

- Mapping Our World: GIS Lessons for Educators (Malone et al., 2005);
- Getting to Know ArcGIS (Ormsby et al., 2004);
- GIS in Schools (Audet and Ludwig, 2000).

To facilitate the construction of a mental model, a geographic inquiry model illustrated in Figure 1 served as a framework for course design and guided the selection of materials, instructional methods, activities, and assessments. The model supports the five skills necessary for thinking geographically: (Skill 1) ask geographic questions; (Skill 2) acquire and organize geographic resources; (Skill 3) explore geographic data; (Skill 4) analyze geographic information; and (Skill 5) answer geographic questions and act upon them (NCGE, n.d.; ESRI, 2006). The five skills comprise critical thinking and incorporate the processes of knowing, inferring, analyzing, judging, hypothesizing, generalizing, predicting, and decision-making.

Course Instruction - The goals of the course were to provide teachers with (1) introductory skills in using a GIS, (2) a geographic perspective in solving discipline-specific problems, (3) skills to apply GIS in support of curriculum standards lesson planning, and (4) ability to locate useful GIS resources relevant to specific subject areas. To introduce GIS skills, the instructor demonstrated daily the technical skills of using GIS and utilized "think aloud" strategies to solve a variety of problems. Teachers practiced these skills using the tutorials in Getting to Know ArcGIS (Ormsby et al., 2004) and exercises on the ESRI Virtual Campus (http://training.esri.com/gateway/). Practice time was given to let teachers use GIS and apply its processes in solving various types of problems. Lessons from the *Explore Your World with a Geographic Information System Teaching Package* (ESRI, 1995a) was used to increase teachers' conceptual understanding of GIS and its capabilities, uses, and ability to promote geographic inquiry. Through the lessons, teachers explored GIS components (i.e., data about the world, layers of data, etc.) and their ability to aid in problem solving (e.g., creating what-if scenarios, altering a map's composition, changing parameters, etc.). Teachers began building a mental inventory of the different types of spatial data that can be included in a GIS (e.g., rivers, streets, land, elevation, housing, etc.) and recognizing some of the interrelationships among these data.

Teachers were provided with a geographic perspective by completing assignments in several modules in the textbook, *Mapping Our World* (Malone et al., 2005) that centered on a geographic inquiry model (GIM). One module examined the correlation of number of phone lines to population counts in world countries. Learners opened an ArcGIS module that displayed a map of world countries. Step one of the module asked a question that could be answered only by using geographic information (Skill 1), "Do the number of phone lines vary proportionately with the number of people among the worlds' most populous countries?" (p. 30). In step two, learners were asked to identify and acquire the geographic data (Skill 2) needed to solve the question. This step was completed by adding population and phone line layers to the world map world. Next, questions were provided to guide the exploration of data layers (Skill 3). Data were analyzed (Skill 4) by calculating and recording the number of phone line for countries. Data were recorded and ranked in a chart for comparisons. The last step in the model required a final action as an extension of problem-solving (Skill 5). One suggested activity was to list one's personal concerns about increasing numbers of phone lines in a chosen country. Another action might be to further explore or add to the existing GIS data to answer other questions.

To extend knowledge of GIS and geographic inquiry to real problems, teachers visited the ESRI website (http://www.esri.com/industies.html) to explore applications of a GIS technology in various industries. They examined the types of data and analyses employed in solving problems. Teachers were asked to look for interrelationships among location, events, and objects mentioned in the applications. The article, *Exploring Common Ground: The Educational Promise of GIS* (ESRI, 1995b) was an assigned reading to offer teachers sufficient rationale for using GIS in their classrooms. The article described the benefits of GIS to engage students in multiple intelligences; foster a mindset of exploration; promote information literacy, spatial awareness, and computer literacy; and provide the tools for students and teachers to become more involved as community participants and citizens. To show how a geographic perspective related to issues relevant to teachers' lives, the county auditor visited the class and presented a PowerPoint slide show on ways that GIS was being used to solve community problems.

As further reinforcement, homework was assigned daily to ensure that teachers were given regular practice in thinking through the steps of geographic inquiry. They were asked to find current articles in newspapers, magazines, television, or the Internet related to a geographic-related problem and answer questions similar to those found in the book, *Mapping Our World* (Malone et al., 2005). Questions prompted teachers to consider the type of problem, data needed, connections between data and geographic locations, relationships among data, and types of analyses required to solve the problem. Daily problems were posted on charts and read by all class members.

Readings in *GIS in Schools* (Audet and Ludwig, 2000) offered accounts of how GIS was used in schools through community-based projects. Projects, centered on standards in the school curriculum, were valuable in prompting discussion of authentic GIS classroom-based activities. Strategies and materials used in the first week of course were intended to help teachers think systematically from a geographic perspective. At the end of the week, teachers brainstormed ideas for using GIS and a geographic inquiry model in their curriculum areas and chose a discipline-specific problem to focus on in designing final projects.

To apply GIS skills in support of classroom curriculum, during the second week, teachers independently created interdisciplinary GIS projects and accompanying lesson plans. Project criteria required teachers to list curriculum standards supported by the project, include the minimum GIS requirements, and use the geographic inquiry method as a guide for writing the lesson (See *GIS Project and Lesson Plan Requirements*). Projects were also to include any components needed for replication of lessons such as worksheets, answer sheets, assessments, interdisciplinary connections, or teacher scripts needed to introduce GIS. Project and lesson plan criteria were as follows:

GIS Project MINIMUM Requirements:

1. At least two layers including a map and attribute table
2. Appropriate symbology that makes the map features easy to understand
3. At least one hyperlink to a web site related to project
4. Layout view displaying all layers, legend, scale, compass, and one related picture

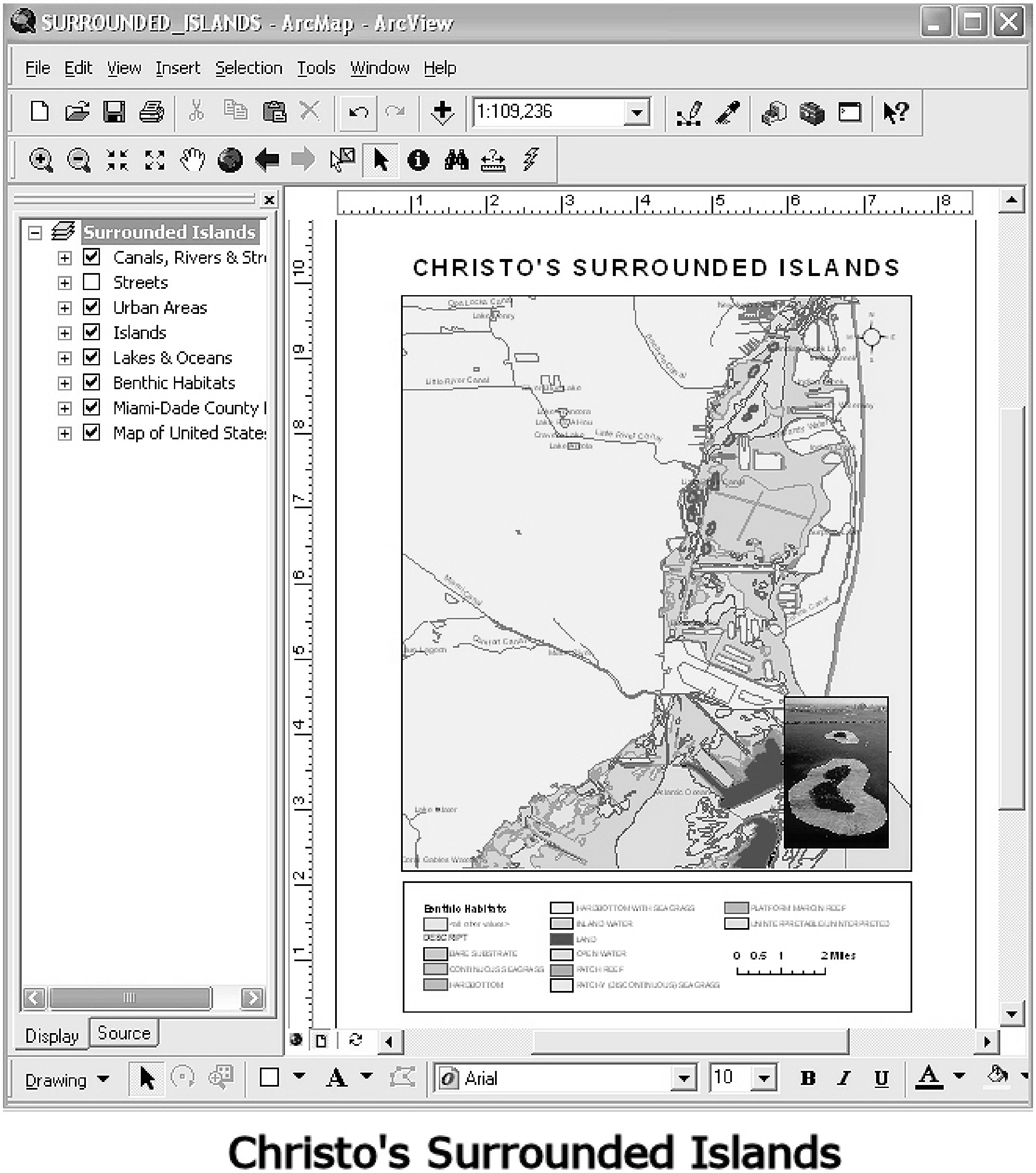


Figure 2. Surrounded Islands GIS project.

GIS Lesson Plan MINIMUM Requirements:

1. An appropriate title describing the topic of your lesson.
2. Goals and objectives the lesson addresses (objectives should be taken directly from the Ohio Dept. of Education curriculum standards).
3. Age or grade level for which the lesson is most appropriate.
4. Length of time to do the lesson.
5. Outline of the content and concepts to be covered, including vocabulary.
6. Possible interdisciplinary links/connections.
7. Materials needed. List GIS files and other materials.
8. Detailed description for how to do activities in the lesson. Use the geographic inquiry method as a guide for writing this section. (Ask, Acquire, Explore, Analyze, and Act).
   The lesson should have students looking for an answer to an overarching question. Students should be asked to form their own hypothesis at the beginning of the lesson and to revisit their hypothesis after analyzing the data.

Include questions to guide students in exploring the data and questions to guide them in performing some form of analysis on the data.
Include necessary steps for students to be able to navigate within the program and to perform GIS operations. Use some of the clips I have provided to show the different tools they should use.
Use separate documents to type student questions so that other teachers could use these to photocopy.
Provide answer sheets for teachers to use in evaluating student work.

9. Assessment strategies to use in evaluating students' understanding of the curriculum content and use of GIS.
10. Ideas for or how the lesson could be modified for higher or lower grade levels or for students with learning disabilities or physical challenges.
11. Provide lesson extensions for further investigation of concepts.
12. A bibliography citing each of the sources for your lesson activities and GIS resources. List the names and internet sites of all GIS files, pictures, text, etc. that you downloaded and any other resources you obtained or suggest in extension activities such as books, movies, music, etc.

Internet links were posted on the course website to help teachers locate appropriate data to design layers and maps in GIS. Teachers were also allowed to use available data from the CD that accompanied the textbook, *Mapping our World* (Malone et al., 2005). The project that follows illustrates how the geographic inquiry and GIS were incorporated into the classroom curriculum.

CHRISTO AND JEANNE-CLAUDE'S SURROUNDED ISLANDS: EXPLORING ART WITH GIS

Created by Phoebe Ballard, The University of Toledo phoebe.ballard@utoledo.edu

The project, *Surrounded Islands* is an exemplary case of how GIS can be integrated into even a most unconventional discipline, art. As a final project, the art teacher chose a particular problem in art related to a geographic location, located the required data to solve the problem, considered analysis needed to solve the problem, and then created the necessary layers in GIS. Afterwards, she designed a lesson plan that introduced the project to high school students. The project included a list of academic standards supported by all activities, a student handout to use with GIS, a teacher tutorial to help students learn to use the features of GIS, and ideas for interdisciplinary extensions. Due to space limitation, the description that follows includes only the essential components of the lesson plan that highlight the art teacher's knowledge of geographic inquiry and ability to integrate GIS in a discipline-specific lesson.

Background - Christo and Jeanne-Claude are internationally renowned for their innovations in Installation Art. Installation Art is "art that is created, constructed, or installed on the site where it is exhibited, often incorporating materials or physical features on the site" (Installation Art, n.d). The husband and wife team have been both celebrated and chastised for their dynamic, colorful and highly unconventional work. Advocates of "art for art's sake," Christo and Jeanne-Claude's art often reflects the culture of the region encouraging viewers to interact with their environment in new and unusual ways. Their site-specific work takes years to complete since environmental and safety concerns are given utmost priority. *Surrounded Islands*, one of the artists' popular works of Installation Art, spread over seven miles and was displayed for two weeks in Biscayne Bay, between the city of Miami, North Miami, the Village of Miami Shores and Miami Beach (Javacheff, 2000). Figure 2 illustrates the GIS project on *Surrounded Islands*.

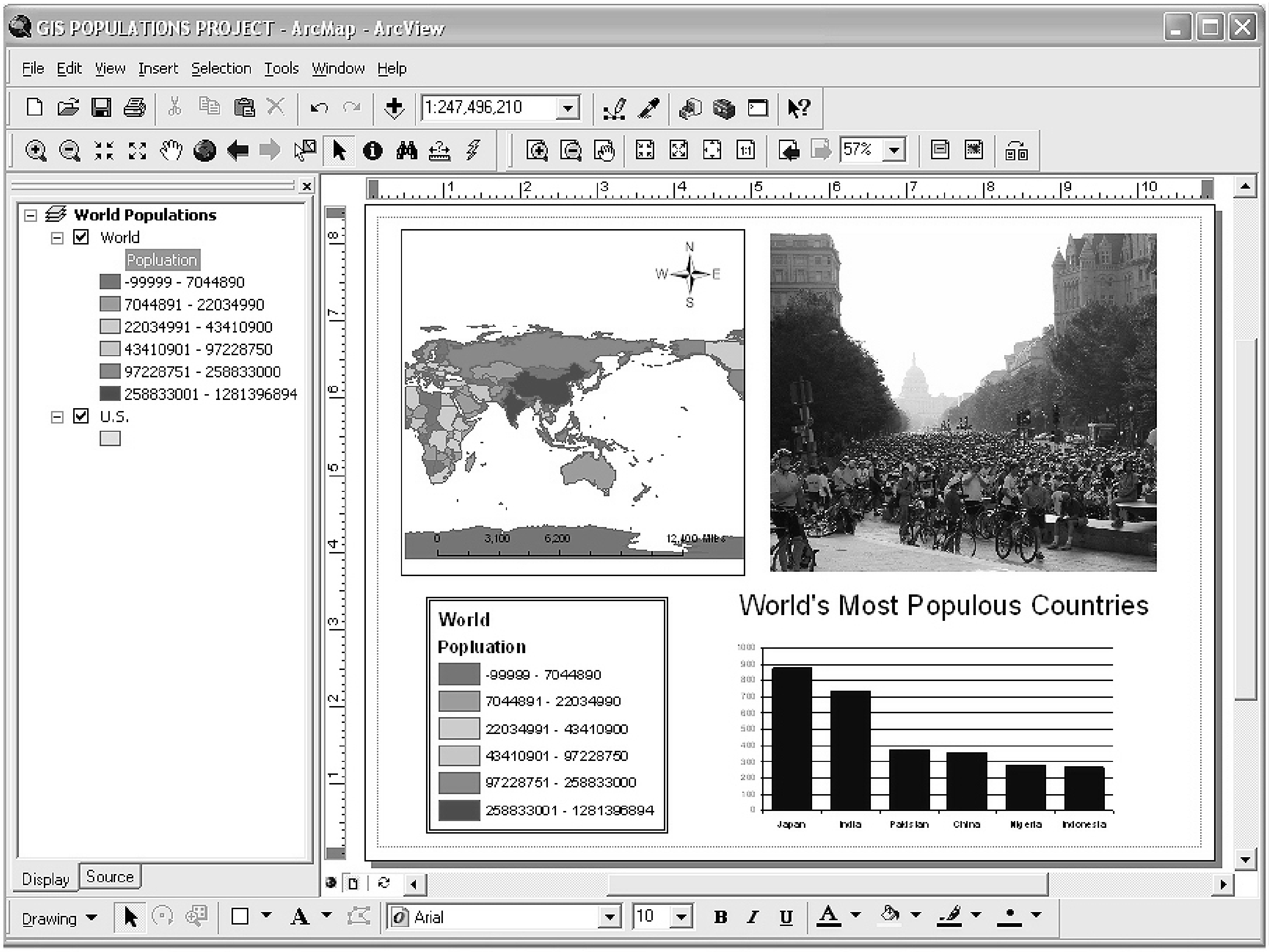
Eleven islands were surrounded with 6.5 million square feet of pink polypropylene fabric that followed the contour of the islands, floated on the surface of the water and extended out 200 feet from each island into the Bay. Over a period of three days, 430 people helped the artists tow the fabric through the water and install it around the islands. Marine and land crews picked up forty tons of garbage from the eleven islands prior to the installation of the art carting away refrigerator doors, tires, kitchen sinks, mattresses and an abandoned boat. The work of art was intended to express the ways that the people of Miami live between land and water. According to the artists, the pink color of the shiny fabric was in harmony with the tropical vegetation of the uninhabited islands, light of the Miami sky, and the colors of the shallow waters of Bay (Javacheff, 2000).

Several State of Ohio Academic Content Standards in high school art are supported by examining the design and installation of the *Surrounded Islands* through a GIS. Students will learn about the location, medium, cultural implications and environmental impact of historic pieces of art (Ohio Department of Education, 2003). They will refine their skills in fine art processes and analysis, and apply visual art, research, and technology skills to communicate ideas in visual form. Students will demonstrate the role of visual art in solving an interdisciplinary problem, and establish and use criteria for making judgments about works of art.

Ohio Academic Content Standards in geography are also supported by the project. Students will learn to use maps and other geographic representations, tools, and technologies to acquire, process, and report information specifically to examine the environmental effects of Installation Art. They will also use mental maps to organize information about people, places, and environments. Finally, students will apply geography to interpret the present and plan for the future (Geography Education Standards Project, 1994).

Procedures - Prior to the GIS lesson, students will watch a DVD video (see "Islands", 2004), and research an Internet site (see Javacheff, 2000) to learn more about the artists and their work. Students will be given several handouts to guide their research and video watching. All questions should lead students to state a hypothesis regarding the following, "Did the *Surrounded Islands* project have a negative or positive impact on the culture of Miami and its surrounding environment?" (Skill 1)

The art teacher acquired GIS data (Skill 2) for this project that included a United States map with layers of information for Miami-Dade County (Florida). Layers are county line; canals, rivers, and streams; streets; urban areas; 11 Biscayne Bay islands; lakes and oceans, and benthic habitats. Population and race data are found in the United States attribute table. Benthic habitats include



World's Most Populous Countries

Figure 3. GIS project, World's Most Populous Countries.

various types of plant growth in the Biscayne Bay such as seagrasses and reefs.

Students will explore the instructor-created project file, *surrounded_islands.mxd* to answer questions about the location of the *Surrounded Islands* Installation Art and its affect on the people, animals, and environment (Skill 3). Questions to explore include: Where is Florida and Who Lives There?" Record the population for different races and make some conclusions about cultural diversity and the population of Florida. Explore the rivers, lakes and streams in Miami-Dade County. What statements can you make about water in Miami-Dade County? Where are the streets on the map located in relation to the water in this county? What surrounds the Biscayne Bay? Explore the Streets and Islands of this area. Which side of Miami-Dade County is closer to the islands? Do you think this side has a better view of the islands than the other side? Why or why not? What kind of information would you need to answer this question? How do you think people get from land on the west side of the Bay to the land on the side east of the Bay?

What kinds of plants or soils are found closest to the islands? What are seagrasses? What kinds of animals depend on seagrass for their survival? What does seagrass need to survive? Think back on the video we watched on the *Surrounded Islands*. Did the fabric prevent light from coming through? Why or why not? The *Surrounded Islands* project was installed for a total of two weeks. What do you think would have happened to the seagrass if *Surrounded Islands* was installed for longer than two weeks? How would a longer installation time have affected the animals that depend on seagrass to live?

To analyze the impact of *Surrounded Islands* on both the environment and its people (Skill 4), students will record the population of Florida, the amount of water in the Biscayne Bay, the shape of the land, the ways that people move around the area, benthic habitat, and the appearance and installation of the art. Students will be asked to draw some conclusions about the impact of the *Surrounding Islands* project on the culture of Miami and its environment then compare these to their original hypothesis. After analyzing the data, students will develop an idea for a piece of installation art and sketch a prototype of this piece (Skill 5). Peer evaluations will be used to assess art designs.

Instructor Evaluation of Surrounded Islands Project - The geographic elements of the project were assessed using the NCGE Geographic Skills Scoring Guide (http://www.ncge.org/about/committees/Geographic Skills By Grade Level 4, 8, 12.doc). In this scoring guide, NCGE skills 2-3 are combined as well as skills 3-4. Each skill was addressed separately in the evaluation. NCGE Skill 5, "Answers" does not require further action. In evaluation, projects were scored with the skills of "Answers" and "Action" combined. There are three scales on the scoring guide to judge the level of skill with the lowest being "Progressing Toward Standard," "Meets Standard," and "Exceeds Standard" as the highest attainment.

Skill 1: Asks Geographic Questions. The project identified a substantial geographic issue, whether the *Surrounded Islands* had a negative or positive impact on the culture of Miami and its surrounding environment. Ample background information provided sufficient understanding of the topic and related issues through watching a video and visiting an Internet site. Further exploration of the topic through specialized geographic questions directed students to broadly explore the data and form a sound hypothesis about the effects of the art on the people, animals, and environment. (*Exceeds Standard*)

Skill 2: Acquire Geographic Information. Multiple research skills were required to locate and collect specific geographic data. While students did not design the GIS project, they had to explore its maps and feature attributes to gather information on benthic habitats, population by race, soils, plant growth, water, and streets. Florida and Miami-Dade County maps were included in the project. Based on worksheets, students would have to thoroughly find and record physical and human characteristic of Miami-Dade. (*Exceeds Standard*)

Skill 3: Organize Geographic Information. Maps were created with sufficient detail, clarity, and appeal to find needed information. When exploring data, students would record information on population, water, land, ways that people move between land and water, benthic habitat, and the appearance of the art. The appearance of the layers was polished and other materials were integrated into the project to ensure that data were organized from various sources. It was obvious that much thought was given to finding and organizing appropriate data so it was easy to find in the project. (*Exceeds Standard*)

Skill 4: Analyzes Geographic Information. Students were asked to interpret the data obtained from maps, attribute tables, layers, charts, art photos, video, and websites in order when asked questions. They also had to synthesize this information to form a sound hypothesis.

Skill 5: Answers Geographic Questions and Action. Combinations of geographic information were presented in the project so students could answer many issues related to the effects of Installation Art. They would have to look for connections between much of this information to answer the questions asked. Students would apply the information gathered in the project to create their own Installation Art. They were also provided other suggestions for extended activities that would require further exploration of the data. (*Exceeds Standard*)

The project exceeded standards in all categories of NCGE scoring guide. It followed a geographic inquiry model in solving a problem related to art. Other educators would be able to replicate this lesson given the design of the GIS project, the lesson plan, step-by-step instructions to assist teachers in using GIS with students, and student handouts. Extensions provided additional activities for further investigations and curriculum ideas offered connections to other disciplines. Accommodations would ensure that all students would be successful completing a similar lesson.

DISCUSSION AND CONCLUSIONS

As suggested by Johnson-Laird (1983), course design and instructional strategies centered on the geographic inquiry model were successful methods of helping teachers understand the relationships between geography and their own disciplines. Final projects and lesson plans provided some evidence of conceptual understanding and ability to apply GIS skills to classroom instruction. On an end of semester questionnaire teachers were asked which concepts or skills were of most interest to them. Some commented that they were surprised at the many types of problems GIS could solve, the different disciplines that could make use of GIS, and the power of GIS to analyze problems in a variety of ways. This conclusion is certainly tentative since much more research is needed in this area.

In support of Patrick et al., (2000), teachers were highly engaged when learning required some form of inquiry. They were motivated and personally interested because learning about GIS and a geographic inquiry model was directly related to their respective disciplines. The model also fostered higher order critical thinking skills (Bruce et al., 1997; Dodson et al., 1999; Hogan, 2000). The types and level of questioning teachers asked of students indicated that they critically and logically analyzed their data from a geographer's perspective. Students were asked not only to locate or identify discrete facts such as location, places, or objects, but also to look for patterns and trends, causes and effects, relationships, and comparable data. Hypotheses were made and evaluations of these were reconsidered after data analysis. Extension activities also demonstrated that teachers expected their students to further explore GIS or use other technologies. In one project, students were required to develop an ad campaign and brochure to persuade potential families to relocate to a city that was identified as an at-risk city.

Included in projects were a variety of interdisciplinary connections. This illustrates that teachers were able to apply methodology and language from several disciplines to examine an issue (Jacobs, 1989). In *Surrounded Islands*, geography was applied to the examination of the effects Installation Art had on a particular area. In another project, algebra was used to examine urban and rural land areas and population densities of several Ohio cities, and to calculate the rate of change in U.S. population over a decade. See Figure 3 for the GIS project, *World's Most Populous Countries*.

In a health-related project, students investigated the rise in obesity levels and in a science project; they examined the effects of plate tectonic activity on the earth and population distribution. Requiring teachers to plan lessons related to their own disciplines made the use of GIS more meaningful and encouraged a greater depth of exploration and learning about their own discipline-specific topics (Lipson, 1993).

Based on the NCGE Geographic Skills Scoring criteria, most of the projects created by students exceeded standards. This gives some indication that teachers can learn to think about problems in their disciplines from a geographical perspective. However, outcomes from a single course tell us little about whether teachers' knowledge or skills will extend beyond the two weeks. In a two-week, introductory-level course teachers learned course objectives but lengthening the course would most certainly increase the probability that teachers would become more confident in using GIS and transfer their skills to the classroom. Teachers need much more time to practice GIS skills and apply these to classroom curriculum. On end of course evaluations, some teachers commented that they would try to use the lesson while others stated it might be impractical in their particular context depending on accessibility of resources and administrative support. It is doubtful that one course would lead to much transfer of learning without offering further training and practice, school-based support, and assistance in software installation.

As expected, particularly problematic was locating appropriate discipline-specific data in the correct format to use in projects. While teachers eventually found data with the help of some Internet links, according to course evaluations, this was the most frustrating part of their learning experience. Teachers considered excellent ideas for projects but in some cases, they had to change directions due to the inability to find suitable data. More time should have been given to helping teachers understand the different kinds of data, preparing it for use in GIS, and locating resources where curriculum-specific data can be found. Without easily accessible data, it is not practical to use GIS in classrooms. As an alternative, students could be provided a CD of data and require that projects be designed around these. However, this may tend to diminish creativity and limit the interdisciplinary connections that can be made when using GIS.

Several other concerns related to textbooks and software are worthy of mention. The book, *Mapping Our World* (Malone et al., 2005) was extremely valuable in modeling lessons based on a geographic inquiry model. The text also demonstrated the types of questions that promote critical thinking. The book, *GIS in Schools* (Audet and Ludwig, 2000) was helpful in showing how classroom or school-based projects could be implemented. However, teachers felt science-related projects were not relevant to their particular disciplines and the size of the projects impractical for teachers or students who only possessed an introductory knowledge of GIS. ESRI has noted the need for two different types of lessons, starter lessons and more involved project that they will publish in the near future (Johnson and Moore, n.d). Short, focused starter lessons will present case studies along with the necessary data and already prepared project files. Longer, more open-ended project lessons will serve as templates for teachers to create their own GIS projects. Short starter lessons may be more suitable for introductory level teachers in the early stages of GIS adoption; however, this will depend on the nature of the lessons. Even though difficult, it was a valuable learning experience for teachers to search for data that supported project ideas based on classroom curricula. Beginning users need assistance and encouragement to think of creative ways GIS can support specific curriculum areas. Without this mental exercise, teachers may learn to use GIS but not acquire the ability to design instruction that integrates its use into classroom learning. Without this necessary support, interest in using GIS in the classroom will not extend past a teacher's initial training.

The GIS tutorial, *Getting to Know ArcGIS* (Ormsby et al., 2004) contained very easy instructions for entry-level students. ArcGIS (version 9) was used for course instruction in GIS only because it was licensed university-wide. This needs further consideration since teachers most likely would not have the software in their schools. A one-computer year license of ArcGIS accompanied the Malone et al. (2005) text but after the license expires, teachers may not have funds to purchase an extended copy of the software. Several free versions of GIS exist but tutorials for these or texts to accompany these versions that model the geographic inquiry model may not be ready available.

IMPLICATIONS

These limited findings do not tell us much about how a program or college can systematically fulfill the recommendations of NRC (2006) to establish guidelines or curriculum for teaching GIS. However, projects and course evaluations demonstrate that GIS can be introduced effectively in an elective summer course and raise teachers' interest level in GIS. Course curriculum, based on a geographic inquiry model warrants further investigation as it was very effective in helping teachers develop mental models similar to that of a geographer. As the course continues to be offered in future years, incrementally it may tend to raise GIS awareness in other teacher candidates and faculty and show them its capability to develop spatial thinking. Most importantly, ready access to user-friendly GIS software and data, training, and classroom support will be essential for teachers and students to use GIS in the classroom. NRC (2006) has recommended a coordinated effort among GIS designers, psychologists, and educators to redesign GIS to accommodate the needs of the K-12 education community. When software used in training is not available in the school, it is highly unlikely that training will transfer.

Course outcomes demonstrate that even a two-week course can be somewhat successful in helping teachers connect geography to their particular disciplines. Teachers were highly engaged because the course required inquiry and independent discovery of topics of high personal interests. A model-centered approach appeared to increase teachers' ability to think critically and use GIS appropriately to solve discipline-specific problems. Admittedly, a single course can provide only minimal evidence of GIS's value when offered in a College of Education. Nonetheless, through sharing the challenges and efforts of this undertaking it may initiate further dialogue on effective ways to integrate GIS in teacher education programs.

REFERENCES

American Association for the Advancement of Science [AAAS], 1994, Benchmarks for Science Literacy, New York, Oxford Press.

Audet, R., and Ludwig, G., 2000, GIS in Schools, New York, ESRI Press.

Butcher, K.R., 2006, Learning from text with diagrams: Promoting mental model development and inference generation, Journal of Educational Psychology, v. 98, p. 182-197.

CEO Forum on Education and Technology, 2000, Teacher preparation Star chart: A self-assessment tool for colleges of education-Preparing a new generation of teachers, http://www.ceoforum.org/downloads/tpreport.pdf (21 June, 2007).

Craik, K., 1943, The nature of explanation. Cambridge, Cambridge University Press.

Environmental Systems Research Institute (ESRI), 1995a, Explore Your World with a Geographic Information System, http://www.esri.com/industries/k-12/download/docs/explore.pdf (2 October, 2006).

Environmental Systems Research Institute [ESRI], 1995b, Exploring Common Ground: The Educational Promise of GIS, http://www.esri.com/industries/k-12/download/docs/xcg.pdf (2 October, 2006).

Environmental Systems Research Institute [ESRI], 2006, Geographic inquiry: Thinking geographically, http://www.esri.com/industries/k-12/education/teaching.html (2 October, 2006).

Geography Education Standards Project, 1994, Geography for Life: The National Geography Standards. Washington D.C.: National Geographic Society Committee on Research and Exploration.

Hong, E., and O'Neil, H. F., 1992, Instructional strategies to help learners build relevant mental models in inferential statistics. Journal of educational psychology, v. 84, p. 150-159.

"Islands," 2004, Christo and Jeanne-Claude, Disc 2. DVD. Prod. Maysles Films: Plexigroup, Inc.

Installation Art, Dictionary.com Unabridged (v 1.1). Random House, Inc. Dictionary.com, http://dictionary.reference.com/browse/Installation Art (23 March, 2007)

Javacheff, C. V., 2000, Surrounded Islands: Miami, Florida, 1980-1983, http://christojeanneclaude.net/si.html (23 May, 2007)

Johnson, D. A. and Moore, S., n.d., Jumpstarting GIS use in the Classroom, ESRI website http://www.esri.com/news/arcuser/0700/cipe.html (24 March, 2007).

Johnson-Laird, P.N., 1983, Mental models, Harvard University press, Cambridge, MA.

Kaplan, D., 2001, Mental model development and reasoning about a causal system in a computer-based inquiry environment, Columbia University.

Kay, R, 2006, Evaluating strategies used to incorporate technology into preservice education: A review of the literature, Journal of Research on Technology in Education, v. 38, p. 383-408.

Kerski, J., 2006, ESRI User Conference and Educational UC Report, http://education.usgs.gov/common/success_stories/esri06t.pdf (27 September, 2006).

Lorenzo, G. and Dziuban, C., 2006, Ensuring the net generation is net savvy, EDUCAUSE Learning Initiative, http://www.educause.edu/ir/library/pdf/ELI3006.pdf (2 October, 2006).

Lucas, E. J., and Ball, L. J., 2005, Think-aloud protocols and the selection task: Evidence for relevance effects and rationalization processes, v. 11, p. 35-66.

Malone, L., Palmer, A.M., Voigt, C. L., Napoleon, E., and Feaster, L., 2005, Mapping our world: GIS lessons for educators, New York, ESRI Press.

McEwin, K. C., Dickinson, T. S., and Jenkins, D. M., 2003, America's middle schools in the new century: Status and progress, Westerville (OH), National Middle School Association.

Merrill, M. D., 2001, A knowledge object and mental model approach to a physics lesson. Educational Technology, v. 41, p. 36-47.

National Council for Geographic Education [NCGE], n.d., Essential school subject. Http://ncge.net/publications/tutorial/overview/ (20 March, 2007).

National Research Council, 1996, National Science Education Standards, Washington, D.C., National Academies Press.

National Research Council, 2000, Inquiry and the national science education standards. Washington, DC, National Academies Press, http://www.nap.edu/catalog/9596.html

National Research Council, 2006, Learning to think spatially, Washington, D.C., National Academies Press.

Oblinger, G. and Hawkins, B., 2006, The myth about student competency

"Our students are technologically competent", EDUCAUSE Review, v. 41, http://www.educause.edu/ir/library/pdf/erm0627.pdf (2 October, 2006).

Ohio Department of Education, 2003, Fine arts - visual arts standards. Ohio academic content standards, http://ims.ode.state.oh.us/ODE/IMS/ACS/Content/fine_arts_standards.pdf

Ormsby, T., Napoleon E., Burke, R., Groessl, C., and Feaster, L., 2004, Getting to know ArcGIS desktop. Redlands (CA), ESRI Press.

Patrick, H., Middleton, M.J., and Taines, C., 2000, Urban students' motivation, collaboration, and thoughtfulness during science inquiry, Paper presented at American Educational Research Association 2000 Annual Meeting.

Seel, N. M., 2003, Model-centered learning and instruction. Technology, Instruction, Cognition and Learning, v. 1, p. 59-85.

Taylor, I., Barker, M., and Jones, A., 2004, Promoting mental model building in astronomy education. International Journal of Science Education, v. 25, p. 1205-1225.

U.S. Department of Labor, 2004, High growth industry profile: Geospatial technology, http://www.doleta.gov/brg/Indprof/geospatial_profile.cfm (30 October, 2005).