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Teaching *with* Rather than *about* Geographic Information Systems

Thomas C. Hammond and Alec M. Bodzin

In 1994, the National Council for Geography Education's Standards Project singled out Geographic Information Systems (GIS) as powerful tools for developing students' geographic skills and perspectives.[1] The group made two predictions. First, that GIS would eventually permeate business, industry, government, and educational organizations. This forecast has been borne out, and GIS is currently used for such far-ranging things as military intelligence, market analysis, assessing real estate taxes, and monitoring animal migrations. The second prediction was that GIS would be "adapted more gradually for use in schools." [2] The adoption of GIS into school settings has been a much slower process.

Since 1994, GIS developers have released free and low-cost GIS versions, such as ArcExplorer-Java Edition for Education (AEJEE) and MyWorld GIS, designed for use in school settings. These educational GIS feature simplified interfaces appropriate for students and are bundled with data sets relevant to the K-12 curriculum. Additionally, teacher-educators and practitioners have written a wide variety of handbooks and disciplinary-based instructional activities for using GIS with students. However, the use of GIS in social studies classrooms remains the exception and not the rule. Teachers continue to wrestle with the challenges of teaching *with* GIS—which is appropriate to social studies education—rather than teaching *about* GIS. Teaching *with* GIS can, for example, develop students' spatial thinking (i.e., their knowledge, skills, and habits of mind to use spatial concepts, maps, and graphs) and processes of reasoning to organize and solve problems. Teaching *about* GIS, on the other hand, involves the mastery of the software—understanding the interface, the syntax for running a query, and so forth. While a recent national reform initiative recommends that K-12 educators use geospatial technologies to foster spatial literacy across the curriculum, most social studies instruction does not take advantage of such applications to promote skills that are essential to citizenship and workforce preparation.[3]

Why has GIS permeated the rest of society but not social education? To be fair, this question has been posed over the years with respect to a range of technologies. Often, these questions are based on an unspoken premise about technology and education, the Mount Everest rationale: classroom teachers must use a tool *because it is there*. The argument for GIS goes beyond such techno-centrism for three reasons. First, the capabilities available with GIS speak to the demands of powerful and authentic social studies teaching and learning. GIS can help address, in some capacity, all 10 NCSS themes. In geography, the use of GIS can prompt teachers and students to move beyond a focus on map reading skills to engage in data interpretation, analysis, and even map-making. Second, GIS offers important pedagogical opportunities. Teachers can use GIS to support and challenge many types of learners, such as those whose geospatial thinking is very concrete and those who use more abstracted strategies. Curricular-based units that employ GIS offer an opportunity for inquiry-based projects and interdisciplinary instruction (e.g., a land use change investigation focusing on sprawl integrates both social studies and science). Third, research on students' experiences with GIS in the classroom has identified increases in affective variables, such as interest and motivation, and also improved academic outcomes.[4]

Both *teaching* and *teaching with GIS* are "wicked problems," in the sense that they involve multiple variables that interact with one another. Effective teaching calls for both learning with understanding and transfer. As an example of learning with understanding, consider a topic such as migration to the Great Plains. In their exploration of the topic, students will need to learn discrete facts: the Homestead Act was passed in 1862, and the bison popu-

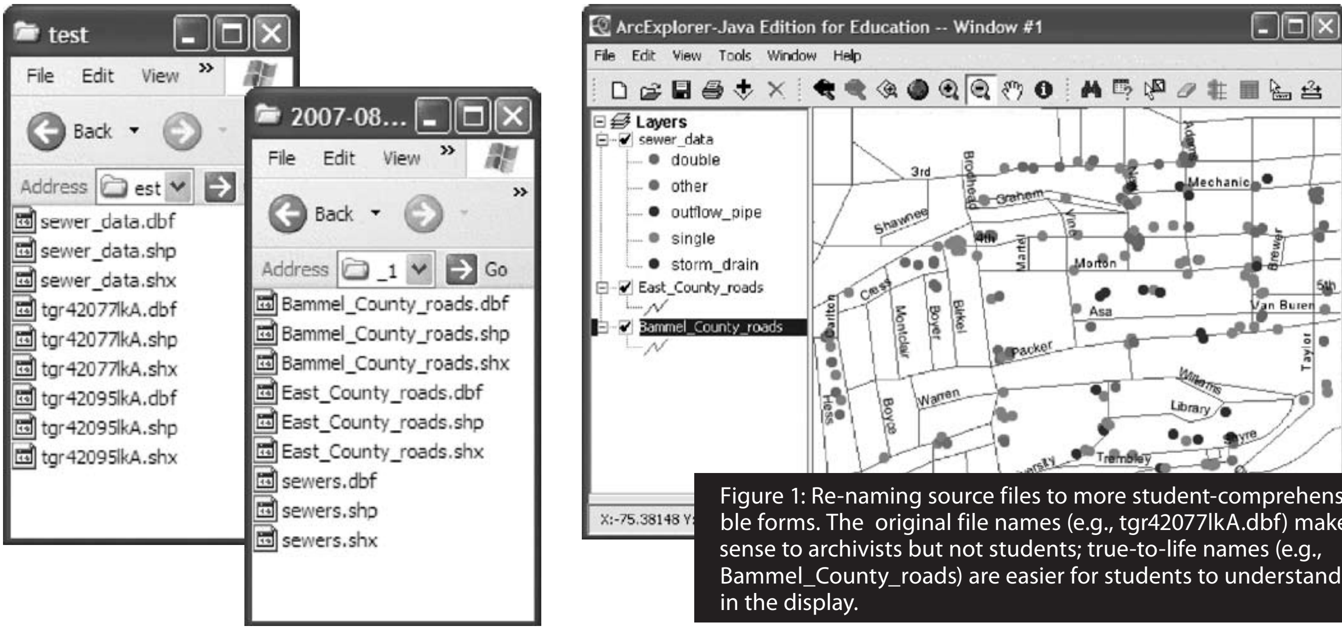


Figure 1: Re-naming source files to more student-comprehensible forms. The original file names (e.g., tgr42077lkA.dbf) make sense to archivists but not students; true-to-life names (e.g., Bammel_County_roads) are easier for students to understand in the display.

lation declined from a pre-Columbian population in the millions down to 1,091 by 1889. However, to allow this information to form a coherent whole, these facts must be placed in a larger context: how and why the bison population (almost) disappeared; how this decline impacted the human (and animal) populations that interacted with the bison; how the demographics of the Great Plains changed between 1862 and 1900. Transfer is accomplished when students are able to extend the insights from one learning experience, such as a unit on the Great Plains, to a new topic, such as the impact of over-fishing in continental shelf waters. Teaching for either learning with understanding or transfer is quite challenging, and requires meticulous instructional scaffolding from the teacher.

One powerful teaching technique for both learning with understanding and transfer is inquiry. GIS serves as a natural tool for conducting powerful, inquiry-driven lessons. Unfortunately, many GIS applications are unwieldy, difficult-to-learn tools (even when using educational versions). Reports from teachers and students on implementations of GIS projects invariably contain descriptions of time-consuming technical challenges. The literature on inquiry-driven projects is similarly fraught, albeit with pedagogical, rather than technical challenges.[5] After all, as geography educator Sarah Bednarz observed, "There is no piece of a GIS that guides or directs students to analyze GIS-produced maps using spatial relational procedures."[6] The teacher must guide learners through this process by weaving together content, appropriate modeling, scaffolds, and technical support.

Our own experience implementing a geography and geospatial inquiry project with middle school students gave us the opportunity to wrestle with the challenges of using GIS in the classroom. This unit posed a driving problem to the students regarding water drainage in the neighborhood. Students first conducted a field survey of storm drains in the neighborhood. The data was loaded into AEJEE for analysis and pattern-recognition, and the unit culminated with a transfer task of planning the locations of storm drains for an adjacent neighborhood. After three successive rounds of instruction and assessments with multiple classes (totaling approximately 200 students), we have identified several strategies for enhancing student understanding and reducing technical friction (and frustration!) in working with AEJEE and other GIS designed for use in school settings.

Teaching with GIS

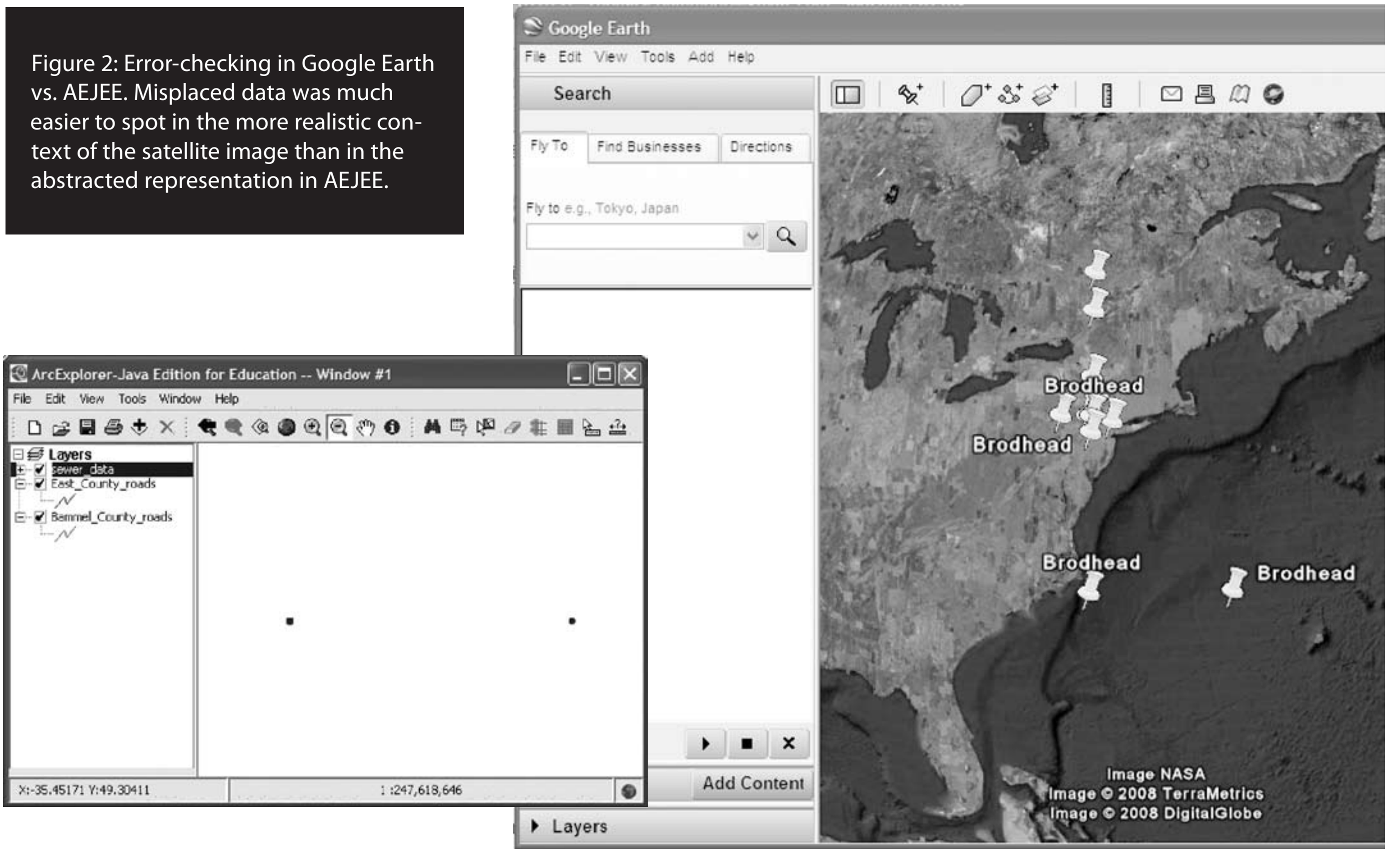
Each of the strategies we developed address two critical questions that students face when working with GIS: "What am I looking at?" and "What am I trying to do?" Accordingly, we have grouped the strategies under these two questions. Our intent, at every step, is to lighten the cognitive load of students and gradually engage them in the process of using a GIS and conducting an inquiry.

"What am I looking at?"

Before students can begin to work with a GIS, they first must understand what they are looking at—what is on-screen and where is it located? We have identified several strategies for helping students build this spatial schema.

First, make the GIS as easy-to-understand as possible. GIS files typically have highly technical filenames. Some of these names may not appear to make much sense. For example, county roads files from the Tiger Census database have filenames such as tgr52077lkA.shp, tgr-52077lkA.shx, and tgr52077lkA.dbf. Once loaded into a GIS, these impenetrable terms become layer names, causing students and teachers to stumble when referring to them. The solution is simple but requires foresight: after downloading the files, rename them to short, unam-

Figure 2: Error-checking in Google Earth vs. AEJEE. Misplaced data was much easier to spot in the more realistic context of the satellite image than in the abstracted representation in AEJEE.



biguous filenames. For example, you might want to rename "tgr42077lkA" to "Bammel County Roads." The three new files will be: Bammel County Roads.shp, Bammel County Roads.shx, and Bammel County Roads.dbf. After renaming the files, add the shape file (Bammel County Roads.shp) to your GIS map.

The next step is to consider your students' use of a map display. When students first look at a map, they have difficulty situating it within a larger context. Textbooks typically address this problem by including an inset "overview" map, showing the detailed area as a box within a larger map. One could use the Zoom-in tool of a GIS to achieve a similar effect; however, we discovered that students often become lost while exploring the map, either by zooming-in until the screen filled with white color or by zooming-out until the entire coverage was compressed to a single dot.

To help students establish a frame of reference, we used a sequence of maps in a variety of media. This process scaffolds the transition from visual to logical ways of thinking about space.[7] First, we had students draw sketch maps of their initial spatial understandings, drawing the study area relative to some accepted landmark. In our project, we asked students to draw a map of the school and the two blocks surrounding it. Students can build upon this initial "naïve geography" to develop more sophisticated ideas. Second, we displayed a map of the study area. If possible, we suggest doing this visual discovery in iterations, starting first in a simple platform—such as using a paper map or a Google Earth display—and then moving to AEJEE or other GIS. Starting with photo-realistic maps or satellite images permits students to focus on the map visualization and not the layers or tools that are embedded in a GIS display. If you wish, you can have students contrast their initial sketch maps with the more formal rendering to refine their mental maps. Furthermore, the more realistic visual allows students to bear in mind the ground truth of a map. An abstract map, such as those typically displayed in a GIS, will represent features with symbols or icons—a city is a dot, and a railroad is a hatched line. These low-information representations can confuse some students. By starting with a simple image, students are better able to recall that the dots represent irregular shapes (e.g., the contours of New York City) and are drastic reductions of complex phenomena (such as the constellation of cities, suburbs, and exurbs running all the way from northern Virginia to eastern Massachusetts). In our experience, the realism and contextual details provided by satellite images help students spatially situate themselves far faster than when using an abstract display. For example, when students examined their collected data for errors, it was far easier to locate mistakes when looking at it as a Google Earth overlay than as a layer in AEJEE—when a push-pin appeared in the Atlantic Ocean instead of the neighborhood around the school (see Figure 2), the students immediately understood the problem!

Once you are working in the GIS, incorporating landmarks and labels

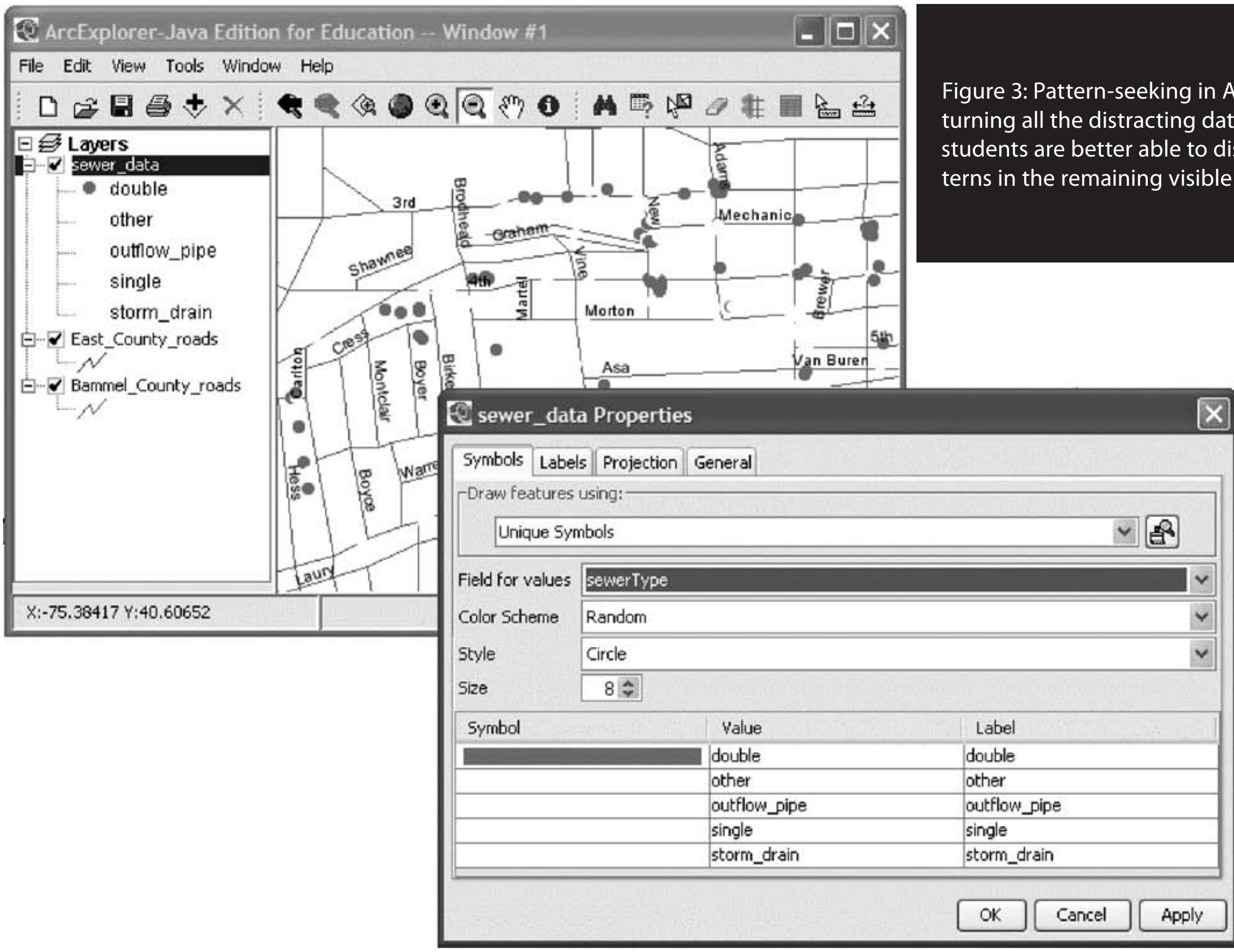


Figure 3: Pattern-seeking in AEJEE. By turning all the distracting data to white, students are better able to discern patterns in the remaining visible data.

will further enhance the students' frame of reference. We created a simple GIS layer of local landmarks that included restaurants, stores, churches, and the school. Students were directed to add these landmarks to their GIS map before adding their collected data for analysis. Landmarks helped the students align the more abstracted GIS representation to their own mental maps. Turning on appropriate labels—and turning off distracting features—will assist in this process. Labels helped establish orientation and provide clear references for conversation. Once we began turning on street labels, students were far more comfortable interpreting the map and discussing the data (see labels displayed in Figure 1).

"What am I trying to do?"

Once students have established a spatial understanding and comfort level, you can begin to unfold the process of using the GIS and conducting the inquiry. We recommend starting in a teacher-centered mode in which you provide a model for the whole class through a large-format, projected image. For example, display the GIS on a large screen and talk through the conceptual steps: "We've taken the streets maps and added the data we collected from the neighborhood; now, we need to find out if there are any spatial patterns." While modeling, keep the focus on the "big picture" rather than the details of the software. We learned not to narrate our actions, such as stating, "I need to run a query, and these are the steps required." Instead, a far more effective practice was to just execute the query while explaining the concept ("Let's have the program count the number of storm sewers for us") and then discuss the results. Students will acquire the procedural details later. Emphasizing concept and process simultaneously will cause many students to lose sight of the task and focus only on the tool.

When transitioning to student use of GIS, scaffold the process by having students use only one tool at a time whenever possible. For example, in order to have students view the full extent of their collected data, we first highlight a specific data layer and then have students zoom to the active layer. We discovered that embedding "how-to" guides for each GIS tool within instructional materials provided much needed support. Many of our students did not want to read; our solution, developed over the three iterative rounds of instruction, was to reduce the amount of text on each instructional handout, include more graphics, and use different font styles to call attention to key terms and processes. Looking back, we realized that the first versions of our handouts were really written for ourselves: the tone was procedural and the scope was exhaustive, including every detail of every step. The later versions of the documents were written with the diverse learning needs of our students in mind.

After students have loaded and explored their data, you can transition to data analysis and pattern seeking. As you work, start as simply as possible by minimizing distractions: switch off unneeded layers and change data attribute colors to focus on pertinent data. For example, when asking students to identify a pattern in the placement of double sewers, we prompted students to turn all other sewer types to white, effectively blanking them out from the map (see Figure 3). As students work towards drawing conclusions, introduce simple quantifications. In our work, we had students count how many sewers are located on intersections vs. how many are not; how many are on east-west streets vs. north-south streets, etc. Once students have determined an initial pattern, granulate the analysis by moving to other data, one step at a time. After our students located a pattern with double sewers, we could ask them to look at single sewers—do they display the same trend?

We also recommend that you open and close any class period that involves hands-on use of GIS with whole-group preview/review sessions. This practice is standard for many instructional methods and long-term projects, but we found it to be especially critical when using GIS. In the beginning of class, these sessions allow the teacher to re-focus student attention on the investigative problem. At the end of class, it provides closure—clarifying for students how the GIS learning tasks relate to the whole inquiry process. Without this re-focusing, students will often mistake the activity for learning *about* GIS rather than *with* GIS.

Conclusion

The above suggestions were gleaned from our experiences using AEJEE and implementing a middle-level unit on geography and geospatial inquiry. They can be applied to the use of other geospatial technology tools and when addressing other social studies curricular areas. Depending upon the lesson, Google Earth can be used as an effective substitute for a more robust GIS. Our GIS sewers unit can be easily adapted for either elementary or secondary students, and the focus on the investigative inquiry problem can be shifted to numerous other topics. Our own on-going work can be viewed and downloaded from **www.ei.lehigh.edu/nes/sewers**. Interested readers are invited to contact us for more information or to discuss their own work.

Notes

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6. Bednarz, "Geographic Information Systems," 194.
7. Wigglesworth, "What is the Best Route?"

Thomas C. Hammond *is an assistant professor of social studies education and instructional technology in the Teaching, Learning, and Technology program in the College of Education at Lehigh University in Bethlehem, Pennsylvania. His research explores technology-mediated social studies instruction, focusing on student- and teacher- constructed materials. He can be reached at* hammond@lehigh.edu. **Alec M. Bodzin** *is an associate professor of science and environmental education in the Teaching, Learning, and Technology program in the College of Education at Lehigh University. He conducts research on inquiry-based models for science instruction with an emphasis on geospatial literacy. He can be reached at* amb4@lehigh.edu.