

Where and Why There? Spatial Thinking with Geographic Information Systems

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Social studies educators have long recognized the importance of developing students' spatial perspective on the world. The social studies curriculum includes many topics that involve an understanding of where people and places are located, the patterns of human settlement, migration, and conflict over time, and the distribution of economic activity and resources around the globe. In a recent report, the National Research Council defined spatial thinking as a combination of three elements: concepts of space (such as distance, proximity, and distribution), tools of representation (such as maps and graphs), and processes of reasoning (such as decision-making).¹ A student is engaging in spatial thinking when she applies her understanding of spatial concepts, spatial representations, and spatial reasoning in a variety of contexts. Computer-based technologies are not required, but geospatial technologies can foster spatial thinking in innovative and significant ways.²

Site Selection Analysis Project

Geographic Information Systems (GIS) is used to make decisions and solve problems involving the spaces and places where we live. A significant benefit of using GIS in education is that the technology is used every day by professionals in the public and private sectors around the globe for a wide variety of tasks. Given the increasing presence of GIS as a vital tool for many professionals, students will benefit from exposure to the spatial thinking processes and GIS tools that are central to a multitude of twenty-first century careers. One of the most common uses for GIS in the public and private sector is site selection analysis. Essentially, this form of spatial analysis involves determining the optimal location for something. For example, retail businesses frequently use site selection analyses to determine the best location for a new store.

We developed and implemented a project for high school geography students that modeled the processes in a site selection analysis using GIS. We sought to explore how spatial thinking could be fostered by using the MyWorld GIS software that was designed specifically for educational uses.³ The task posed for the students was to (1) perform a site selection analysis using GIS to determine the best location for a new business of their choice, and (2) present and justify their ideal location with a PowerPoint presentation. We divided the project into four parts that were completed during the course of three 80-minute "block" class periods. Students were given a hand-out with "Think About" and "To Do" prompts for each part (see Table on pages 114–115) and a "Proposal Checklist" on which to record their responses.

When working with computers in the classroom, it is crucial to have a flexible

structure that fosters a collaborative relationship between the teacher and the students. To establish this classroom tone, Mary Curtis (the classroom teacher for this project) was honest with the students about the level of her knowledge of GIS in general and the MyWorld GIS software specifically.⁴ This honesty builds respect and rapport with the students. A few simple rules were also established:

1. Your teacher is not a technowizard. She may need to "figure it out" occasionally. If you have figured out a tech trick, share it with the class.
2. Your "ideal" data may not be available in the given data sets. Be flexible and use your problem-solving skills to "whittle it down" to what you need.
3. Follow the instructions and work at your own pace. Mary intentionally kept the pace slower than usual so that those students who were not computer savvy would begin to feel more capable. Those who were able to work ahead were allowed to do so with the understanding that they would need to be patient when they needed Mary's assistance.

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Table 1: Student Guidelines for Site Selection Analysis Project

		Think About:	To Do:
Part I: Planning	1. Establishing a Business	What type of business would best match your knowledge and interests?	Write a brief description of the type of business that you would like to open.
	2. The Ideal Customer	Who are the people who will want your goods and services?	Write a description of your ideal customer.
	3. The Ideal City	What physical and human characteristics does the city need to have for your business to be most successful?	Write a description of the ideal city for your businesses.
Part II: Exploring	4. Looking at the Data	What data are available to help you find the ideal city for your business?	Open the MyWorld Project and list the 11 layers of data that are available.
	5. Exploring U.S. City Layers	What city level data are available?	<ul style="list-style-type: none"> • Make the U.S. City layer visible and active. • Open the table for this layer and scroll across the top to view all of the attributes (column headings). • Pick 3-5 attributes that you think will be relevant for site selection.
	6. Exploring U.S. County Layers	What county level data are available?	Repeat the steps above with the U.S. Counties layer.
	7. Exploring Other Data Layers	What other data might be relevant for your analysis? Will your business need to be close to a major highway? How might climate impact your business?	Review the data available in the tables for the remaining layers. Select 3-5 additional attributes that might be important for your business.
	8. Prioritizing Attributes	Which of the attributes that you've listed are most important?	<ul style="list-style-type: none"> • Compare your list with your description of your ideal customer. • Create a rank ordered list (most important to least important) of at least 10 attributes. • Write the name of the layer where the data can be found next to each attribute.
Part III: Analyzing	9. Querying the Database	The procedure that you follow for your analysis will depend on the data that you are using and what you want to find out. When you perform a "query" you are simply asking a question of the database.	Perform a series of queries that will help you to narrow down your list of target cities.
	10. Selecting Target Cities	What are the top 5 cities in the U.S. that meet some or all of the criteria you identified for your ideal city?	Make a list of the Top 5 cities.
Part IV: Deciding	11. Using Other Data	What additional information would be helpful in making the decision about where to locate your business?	Brainstorm a list of characteristics that aren't included in the GIS data that would be helpful in narrowing your final selection.
	12. The Final Selection	Which city best meets your criteria based on the data that you have available?	<ul style="list-style-type: none"> • Choose one city • Write an explanation for why you selected this city • List additional information that you still need to know.
	13. Presenting your plan	How can you persuade a potential investor that your business is likely to succeed in this location?	<p>Create a PowerPoint presentation that includes slides of the following:</p> <ol style="list-style-type: none"> 1. The name of your proposed business and a brief description of the goods/services your business will provide. 2. A list of 5 criteria that were used in the selection of the location for the business. 3. A map showing the top 5 cities that resulted from your site selection analysis. 4. A map of the final location 5. Maps and graphs from MyWorld that demonstrate how the location you selected meets your criteria. 6. A list of additional information that you will need before making a final decision.

Example:	
I would like to open an ice cream restaurant that specializes in flavors and desserts that are popular in Latin America. I think I will be successful in this business because I've worked in an ice cream restaurant before. It is also uncommon to find a restaurant in the U.S. that specializes in the tasty desserts that are found in Latin American countries. I will call my new business "Casa de Helado"	
My ideal customer would be Hispanic or someone who has been to Latin America and likes the desserts there. This is a family-oriented business so my ideal customers would be families with young children. My ideal customer will also need some disposable income to be able to afford a special treat like ice cream.	
I will need a city with a large Hispanic population, lots of kids, plenty of sunshine, warm temperatures, and very little snow. It might also be helpful if my business is located in a place that attracts tourists since they would also be likely to spend money on ice cream. It doesn't really matter if my business is close to a river, airport, or railroad. It would be good to be close to a highway so I can have ingredients and other materials shipped to my store easily. It doesn't really need to be close to any particular physical feature, but a location close to the ocean and a beach might be good.	
U.S. Cities, Major Highways, U.S. Rivers, U.S. Counties, U.S. Lakes, U.S. States, Climate Classes, Average Precipitation, Average Temperature, Average Sunshine, Continents.	
Elevation, Hispanic, Age 5-17, Married w/Children Households	
Median Value (homes), Population (2000), Median Age, Families, Average Family Size	
Interstate highways, Low precipitation, High Average temperature, High Average Sunshine	
1. Hispanic population (U.S. Cities)	6. Population 2000 (U.S. Counties)
2. High Average Annual Temperature (Average Temperature)	7. Average Sunshine (Average Sunshine)
3. Married w/Children Households (U.S. Cities)	8. Families (U.S. Counties)
4. Median Home Value (U.S. Counties)	9. Average Family Size (U.S. Counties)
5. Interstate Highways (U.S. Highways)	10. Low Precipitation (Average Precipitation)
My first criterion is a high percentage Hispanic population. The data in the U.S. Cities table provide me with numbers of Hispanics in each city, but not with the percentage of the population that is Hispanic. Since I want a population with a high percentage of Hispanics, I will calculate this percentage. I want to narrow my selection of cities to those with a high percentage Hispanic Population. I will select greater than 60% as my definition of "High".*	
1. Robstown, Texas	4. Tamiami, Florida
2. Laredo, Texas	5. Kendale Lakes, Florida
3. Sweetwater, Florida	
I might also want to look at which of these cities:	
<ul style="list-style-type: none"> • attracts more tourists • has available and affordable commercial and residential real estate • doesn't already have too many ice cream stores • has a low crime rate 	<ul style="list-style-type: none"> • would be a nice place to live • has good schools • provides better support for new business owners in terms of tax incentives, restaurant owners' associations, and reasonable commercial real estate regulations.
I chose Laredo, Texas, because between the final cities Laredo has a larger population with a larger percentage of Hispanics and Married with Children Households. Laredo is located on the Rio Grande River and Interstate 35. Laredo is also where many people cross the border between the U.S. and Mexico. Its location on I-35 and the border provides a great location for receiving goods from both the U.S. and Mexico. I still need to know more about the real estate market, crime rate, taxes, competition from other ice cream shops and restaurants, and the specific locations in the city that would be suitable for my business.	
See Figure 1 for an example of an image that might be included in a PowerPoint presentation.	
* Students will need to think about these "cut-off" numbers for their analyses. One approach is to view the data table and sort the records from high to low or from low to high. This will give the students a sense for the distribution of the data and can help them to make a choice about a good number to use when selecting the records to keep and the records to exclude.	

4. When (not if) you get stuck during the analysis phase, “play” with the software to see if you can figure out a solution. If that doesn’t work, ask someone in the class for help. If you still can’t figure it out, ask the teacher for help. Nine times out of ten, someone else usually had the same problem and had figured out the answer.
5. Keep track of your data and analysis. Students were instructed to write down the data they found necessary, where they found it (city vs. county layer), and the track of their analysis.
6. Learn from each other. This did make for a noisy class—but it was a good noise that reflected the learning taking place. Allowing students to have the freedom to explore will help ensure they stay on task and will help the teacher learn too.

Stage One: Planning

The first stage of site selection analysis involves determining the criteria for the ideal site. This mirrors closely the goals of critical thinking and decision making in which students must establish criteria upon which to evaluate an idea or make a decision. We have found that students frequently want to make a decision first and then find information that will support their choice. We structured the project such that students were guided to think through their criteria prior to considering specific locations. We provided the students with three “Think About” questions during this stage: (1) What type of business would best match your knowledge and interests? (2) Who are the people who will want your goods and services? And (3) What physical and human characteristics does the city need to have for

your business to be most successful? These questions were designed to guide their thinking toward the criteria that would be important and away from a pre-selected city that they wanted to choose. We found that some students still attempted to pick a city first and then choose criteria that would fit their choice. It remained an important task to monitor students during this stage and to challenge them to think beyond a pre-determined choice.

Students selected a wide variety of businesses to propose during this stage, such as

- “A big, huge hotel with a rustic country appeal, but very new and classy.”
- “An eco-friendly outdoors store.”
- “A water park with water slides, gift shop, and entertainment”
- “A bookstore with a coffee shop, lounge, and pub”

Once students described their proposed business they were challenged to think about the human and physical characteristics of the city where such a business might thrive. Because students were familiar with the cultural/physical geography of the United States, they were able to sift through their prior knowledge to create a general idea of the types of data and the intersection of data layers necessary to complete their assignment. Through this process, students engaged in spatial thinking about concepts such as proximity, clustering, distribution, and relationships.

Stage Two: Exploring

The second stage in the project involved exploring the geographic data available for their analysis. This stage paralleled an important step in the workflow of professional GIS users. It also introduced students to the reality that data analysis is constrained by the quality and availability of data. For example,

some students wanted to know the income levels of the people in certain areas. However, income was not a given characteristic thus forcing them to contemplate data that might reflect income level. Students had to critically evaluate the data available to them to determine which were relevant to their proposal and their decision-making process. Furthermore, the students had to prioritize and defend their decision to include specific data in their analysis. For example, they had to determine if the proximity to a river was more important than the amount of people in an area. Each time the students evaluated the data layers, they had to critically analyze the spatial relationship between the sets of data. Students explored the data layers and tables that come with the MyWorld software and gained an understanding of differing scales of data (city versus county level) as well as the structure of the database. Some analysis was better suited to county versus city data. For example, median home values were available at the county level, but not at the city level. These tasks involved students in spatial thinking about how geographic data had been represented in the database, as well as important spatial concepts such as scale.

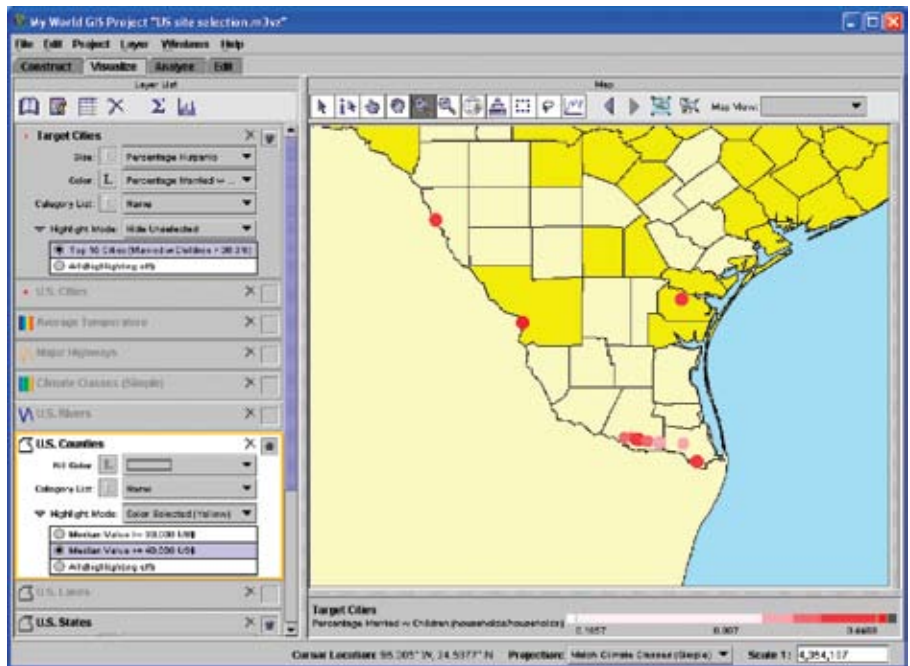
Stage Three: Analyzing

The data analysis conducted in the third stage involved one of the key features of the MyWorld software. The MyWorld interface was constructed with tabs so that users can easily switch between the modes of construct, visualize, analyze, and edit (See Figure on page 117). This feature differs from a professional GIS software interface that typically requires users to open new windows and toolbars. Another key difference is that the “Analyze” mode of MyWorld provides users with a set of common analytic functions and a series of drop-down menus that guide the process of constructing a query or operation. Students had to think through the series of queries that needed to be performed in order to narrow down their choices.

For example, a team of students might want to narrow their search to cities that have a population greater than 50,000. To do this, they would perform a query that asks the GIS database to select all of the cities with a population greater than 50,000. In the Analysis Mode of MyWorld this is accomplished through the *Select... By Value* query. The series of drop-down menus allows the students to construct a query that reads:

Select records from: U.S. Cities
Whose: Population
Is Greater than or Equal to: 50,000

To accomplish this query, the students need to know which data layer they wish to query (U.S. Cities), which attribute or column within that layer contains the information they want (Population), and which records or values within the table should be selected (greater than 50,000). Since they have explored the data in the previous stage and recorded the attributes and layers that are relevant, the task at this stage is to locate the specific records that match their defined criteria and to evaluate the new map to ascertain where the analysis performed provides the desired spatial relationship. A valuable challenge for students is to consider how the information they need is represented in the database. For example, one group wanted to include only coastal cities. The database does not include a classification for cities that are on the coast, but the students realized that they could search for cities by elevation to narrow their selection. Each query should build upon the previous query. For example, the students would have selected all of the cities with a population greater than 50,000 *and* an elevation of less than 300 feet. The ability to reason spatially is honed each time a student makes a query and evaluates the results. Students are able to save the results of each query as “radio buttons” that can be turned on and off in the visualize mode. This allowed them to view the results of their queries and to perform additional queries based on those results.



Map of South Texas cities with a population that is more than 60% Hispanic. The cities are displayed in shades of red to show which cities also have a high percentage of Married with Children households. The darker shades indicate higher percentages. The counties that are shaded yellow have Median Home Values of more than \$40,000.

Stage Four: Deciding

During the final stage of the project, the students selected a particular city as their “target city” for locating their business. Before making the final selection though, students were guided to think about the additional information they would need to make a good decision. This step is an important component of critically evaluating the available data, as well as evaluating the decision-making process. To support this critical evaluation of their thinking, students were prompted to think about (1) What additional information would be helpful in making the decision about where to locate the business? and (2) Which city best meets your criteria based on the data that you have available? Once students made their selections, they constructed PowerPoint presentations that included at least six slides:

1. The name of the proposed business and a brief description of the goods/services this business would provide;

2. A list of five criteria used in selecting the location for the business;
3. A map showing the top five cities that resulted from the site selection analysis;
4. A map of the final location;
5. Maps and graphs from MyWorld that demonstrate how the selected location meets the student’s criteria;
6. A list of additional information the student will need before making a final decision.

On the final day of the project, the students presented their results and verbally defended their choices to the class.

Conclusion

The MyWorld software proved to be a valuable—though not perfect—tool for this project. Despite the education-

Instructional Technology Editors Michael J. Berson and Meghan McGlinn Manfra wish to thank the following individuals for their thoughtful reviews and feedback for this issue of *Social Education*.

Marsha Alibrandi, Fairfield University

Ilene Berson, University of South Florida

Cheryl Mason Bolick, The University of North Carolina at Chapel Hill

Joseph Braun Jr., National Council for the Social Studies and Illinois State University

Margaret Smith Crocco, Teachers College, Columbia University

Richard Diem, The University of Texas at San Antonio

Tony Dralle, East Carolina University

Joseph Feinberg, Georgia State University

Adam Friedman, Wake Forest University

Tom Hammond, Lehigh University

David Hicks, Virginia Tech

Patrice Preston Grimes, University of Virginia

Bruce Larson, Western Washington University

George Lipscomb, Furman University

David Locascio, Longwood University

Anand Marri, Teachers College, Columbia University

Andrew Milson, University of North Texas

Jason O'Brien, University of Alabama in Huntsville

Joe O'Brien, University of Kansas

John Saye, Auburn University

Eui-kyung Shin, Northern Illinois University

Jeremy Stoddard, College of William and Mary

Dan Stuckart, Wagner College

Cheryl Franklin Torrez, University of New Mexico

Phillip VanFossen, Purdue University

Mark van 't Hooft, Kent State University

Shannon White, University of Missouri

friendly design of the software, the students struggled with computers that crashed as they ran their queries and the lack of time needed to become familiar with a new interface and tools. One of the primary student complaints was the lack of flexibility in creating customized map layouts. Students desired greater ability to manipulate the final map of their selected city than the software allowed. The students relied on screen captures to import their maps and images to their PowerPoint slides which required additional manipulation, and thus consumed valuable time. Overall, most students found the software easy to use, but they were understandably frustrated when their computers crashed as they ran analyses. The students were encouraged by their teacher to consider this a lesson in flexibility and problem solving. Most students took the challenges in stride and worked around the obstacles they encountered. Although such tribulations can be a source of anxiety for the teacher, working through such technological challenges fosters a problem-solving ethic among the students and prepares them for the realities of the twenty-first century workplace.

The results of this project reveal much about spatial thinking with GIS. Most importantly, the project demonstrates that a powerful geo-analysis tool can be used successfully in a classroom to promote students' spatial thinking. The task must be structured in a way that guides students through the thinking process without doing the thinking for them. We accomplished this balancing act by dividing the project into the stages of planning, exploring, analyzing, and deciding. These four stages modeled the workflow that a professional GIS user would follow while also stimulating spatial thinking and problem solving throughout the process. In addition to the spatial thinking benefits of the project, we found that students were engaged by the authenticity of the site selection analysis task. They commented positively about the

opportunity to see how geography and GIS are applied in the real world. The students also were enthusiastic about the freedom they were given to choose their own businesses and to decide which data were important to their proposals. A few of the more advanced students suggested that additional online or library research should be required so that they would be able to make a more informed choice. Given an authentic task and a powerful geospatial technology tool, these students engaged in spatial thinking with GIS. 🌐

Notes

1. See National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum* (Washington, D.C.: National Academies, 2006).
2. See Sarah Witham Bednarz and Robert S. Bednarz, "Spatial Thinking: The Key to Success in Using Geospatial Technologies in the Social Studies Classroom," in *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, eds. Andrew J. Milson and Marsha Alibrandi (Charlotte, N.C.: Information Age, 2008), 249-270.
3. See Daniel C. Edelson, David A. Smith, and Matthew Brown, "Beyond Interactive Mapping: Bringing Data Analysis with GIS into the Social Studies Classroom," in *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, 77-98; and the MyWorld website at www.myworldgis.org/.
4. When Mary began this project she was familiar with ArcView GIS and some Internet-based GIS sites, but had never used MyWorld GIS in a classroom.

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