# Introducing GIS in the classroom: A Process Framework

**By Thomas R. Baker, Ph.D. (tbaker@ku.edu)**

**Draft Version 1.0a: June, 2000**
**Draft Version 2.0: February 1, 2003**

A map is a two dimensional graphic representation of the three dimensional configuration of the earth's surface. As an abstract representation, maps reduce the number of variables and simplify reality into an understandable bit of information. Even a simple map, however, contains a great deal of information. Students need help and guidance as they try to interpret and understand this complex visualization, whether the map is on paper or generated from a database in a Geographic Information System. By identifying a series of steps, we can better understand how to help students on a pathway to thinking in more abstract modes, where divergent and creative efforts are required. By identifying a series of steps, it is also possible to design GIS supports for all levels of existing classroom instruction, including Project Based Learning. Without an adequate understanding of the complexities of the GIS and where learners are in the learning environment, we are likely to overwhelm students with abstract information that they cannot understand. We end up with fragmented units that only teach "how to use the GIS software" or lessons that work only in special isolated circumstance.

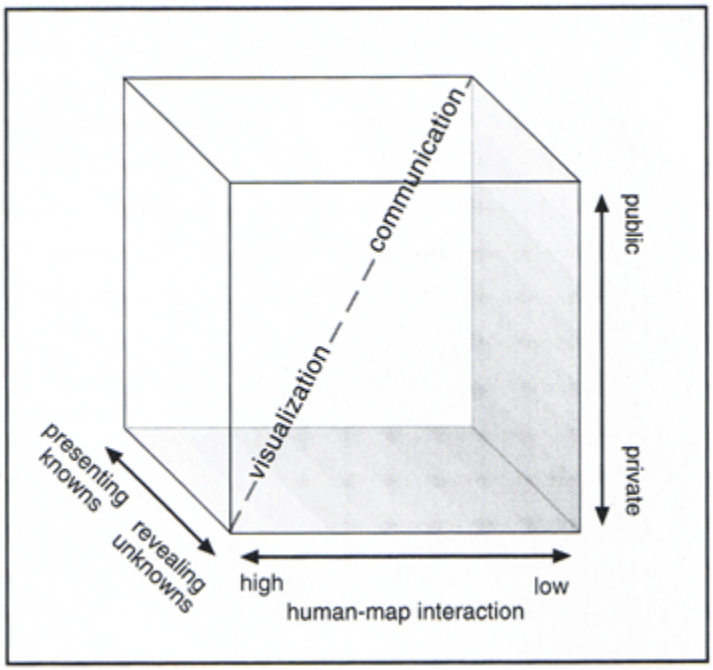



**Figure 1: Cartography-Cubed from Slocum, 1999**

## Foundations

In 1994, geographer Alan MacEachren presented his ideas for "map use tasks". In his model, the software user interacted with a GIS at differing levels of complexity, privacy, and discovery. In MacEachren's diagram, the user progressed along a diagonal from *communication* to *visualization* (see figure 1). Along this diagonal, MacEachren assigned stages to map use activities that can be adapted for a learning sequence for introducing students to GIS. The sequence presented here is not MacEachren's sequence, but rather an adaptation for instruction in classroom use of GIS. These steps are:

- Presentation – the display of a static map or GIS output, usually for an audience
- Exploration – a simple examination or addition to data presented in the GIS
- Analysis – selection of features based upon criteria

- Synthesis – recombination of existing data or creating one's own data into a new map
- Visualization – a dynamic process of searching for new spatial patterns by altering the way the data is represented.

MacEachren's original sequence was represented within the cube (figure 1), where stages were placed upon the *communication-visualization* diagonal. In his cartography-cubed diagram, each axis represented:

- X Axis - High human to map interaction ranging to low interaction
- Z Axis - Known data versus unknown data
- Y Axis - Single viewer to a large public group.

Similar to MacEachren's sequence, in 1956 Benjamin Bloom presented a classification of intellectual behaviors, where task complexity basically increased with each taxonomic branch (WestEd, nd.).

- Knowledge – seeking facts, testing recall and recognition
- Comprehension - translating, interpreting and describing
- Application - to situations that are new or unfamiliar by demonstrating
- Analysis – by creating categories or distinguishing events or behaviors
- Synthesis – combining or organizing components into a new pattern
- Evaluation – judge according to some criteria and provide a rationale

This sequence represents a general structure of intellectual behavior of great value that should be applied as we develop a GIS process framework. Bloom's intellectual behaviors lead us to the present framework for student interactions with GIS. It is important to realize that a one-to-one match between process framework and Bloom's taxonomy is not intended. The two sequences are placed side-by-side to illustrate the relationships between the two sequences. Likewise, it is important to realize that any specific GIS task can breach into multiple areas of the process framework.

**Presentation**

In Presentation, students or teachers show maps to an audience. The audience does not interact with the map, but passively receives the information and context selected by the map presenter. An example of presentation may include a teacher incorporating a GIS map into a PowerPoint presentation. The map is static and does not allow for any interactivity. Other examples may include a traditional weather map in a newspaper or "You are here!" maps at the mall. These maps are characterized as having the lowest levels of interactivity, simply presenting known information. MacEachren argues that in Presentation, maps are most often experienced in large groups. This level of map use, arguably, requires the least skill by the student *during the presentation task itself.*

This level of GIS use coincides well with didactic, lecture-style teaching formats. It disallows for interaction with data or evaluation of unknowns and is typically set in whole class or lecture hall settings. Presentation of GIS maps is relatively stable, with

relatively few chances of technical problems or errors. Presentation of map data from a GIS will be the focus of the next module, module five.

**Exploration**

The task of exploration is one of data discovery, investigation and untargeted or unintentional searching. At this point, students start to "fool around" with GIS software and data. Likely, at this point, students will turn layers on and off, make layers active, or even add/delete existing data layers in a GIS. Exploration is a stage where students can “check-out” immediately available data layers and simply "see what's there". For example, a student may wish to turn on a layer representing state boundaries, as an overlay for other geographic features, later adding cities, fault lines, and points of seismic activity in order to get a feel for how close to danger his or her local community lies.

With the popularity of Internet-based mapping on the rise, it's important to note that many of these applications fit into the Exploration node on this sequence. Most Internet-based maps, like the Winter Bird Survey map (at http://pathfinerscience.net/maps/winterbirds) allow the user to query different combinations of data, providing a limited set of data options for Exploration and representation. The use of Exploration is an ideal starting point for students working with a GIS in a situation where students must understand the concepts and content of new data. While Exploration activities can be directed through worksheets, more often than not this is an informal process that is relatively organized, random, and un-targeted. At this node of the sequence, technical stability and human error are still reasonably negligible. However, teachers and students will often begin to recognize the limitations of the local PCs and networks, particularly when working with raster-based GIS data. The phase does not have a module dedicated to it, but the informal process will be identifiable in all of the remaining practicals.

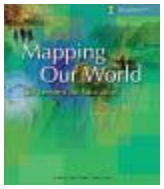
**Analysis**

Analysis is generally considered to consist of processes where data layers are compared and contrasted against one another. In some cases, data are identified based upon relationships with other data. For example, a common Analysis task is the selection of a suitable location, based upon some criteria. A biologist wants to identify all westward-facing slopes with an angle greater than 20 degrees along the Wakarusa watershed. By identifying these locations, the biologist can better choose study sites for an investigation into local riparian habitats.

Analysis tasks could include identifying what's inside, outside, or nearby another object or class of objects. For example, a developer may want to identify land parcels within 150 feet of primary roads inside Douglas County. Analysis could also consist of looking for points where deer populations have been identified within the boundaries of state or federal parks. Analysis may be used to recognize areas of the greatest or least density, for example people per square mile.

The use of GIS Analysis in the classroom is often directed with worksheet activities. Specific directions, indicating which buttons to push and which layers to

manipulate can rigidly control classroom activity. It is for this focus on buttons and operational tasks that Analysis activities are often used to teach *about* the GIS, resulting in "*buttonology*" activities. On the other hand, Analysis could consist of a question presented by a teacher or generated by students. Such a question may sound something like, "Where are the most likely locations in Johnson County for animal road-kills to occur?" Such an open-ended question could require far more thought and creativity by students than following a simple worksheet. To name a few issues, students must be able to identify sources of shelter, food, water, mating practices, and major roadways with projected traffic patterns. In some cases, this may even involve students doing field-work to collect their own data. Some published collections of Analysis lessons include ESRI's Mapping Our World, a text of world geography activities that use GIS, and ArcLessons (http://kangis.org/arclessons) an online library of science and social science lessons.




Depending upon the comfort of the teacher, the GIS and science skills of the students, and the classroom environment, Analysis activities can be performed at varying levels. Analysis will likely require that data be acquired from beyond the immediate computer. Data projections, datums, file formats and compression issues will likely come into play. Analysis typically tests the robustness of the local PC computers, the network, and cognitive abilities of the students. Module six presents a typical Analysis activity that could be provided for classroom use.

**Synthesis**

The idea of creating new data layers and/or recombining existing data layers into new, previously unknown patterns is the hallmark of Synthesis. In the processes of Synthesis, students take the knowledge they have previously learned about science and GIS use and apply the knowledge to a new, unknown situation. A simple synthesis activity may include adapting a previous study to conform to the question of the current research. For example, students may wish to investigate deer road-kills in Johnson County. In this way, they may be able to take elements of a deer population study and the road kill study, creating a potential solution set using the same processes and original data sets. The students synthesize, or recapitulate previous data in such a way as to make it useful for the present study.

Synthesis exercises, like Analysis, require a robust computer and network, capable of transferring large data files or processing graphically intense commands. Pedagogically, Synthesis can be framed within a worksheet environment, but is substantially more thought-provoking if left open-ended. A suitable question for guiding student research that focuses on Synthesis may include, "How and why are local deer populations represented in county road-kill counts?" Such questions, when preceded by the proper units of deer population and road kill surveys, represent an excellent point of engagement for Synthesis questions. Module seven uses Synthesis to organize GIS activities.

**Visualization**

Visualization, while exact descriptions vary, is generally the process of searching for new patterns within the data layers. Often such patterns can only emerge after numerous iterations within an analysis or synthesis activity. Specifically, visualization can include the manipulation of the way the data is represented by the mapmaker. Alterations of the classification (including color palette and legend types) or map styles are considered potential Visualization approaches. More recently three and four dimensional modeling and animations have been considered among the foremost efforts to create Visualizations.

In the 1987, McCormick et al. first named a new subfield in cartography, referred to as *"scientific data visualization"* , a field designed to "leverage existing scientific methods by providing….insight through visual methods" (p.3). In scientific data, multivariate data sets are explored in spatial and non-spatial ways, which could include medical imaging, molecular modeling, and fluid flow to name just a few.

Visualization is not readily controlled with worksheet-driven GIS activities. As Visualization is the search for unknown patterns within the dataset, it only makes sense that such patterns not be pointed out by using directive, worksheet activities. Visualization is often most compatible with classroom environments using Problem Based Learning (PBL) or open-ended scientific inquiry. Each of these efforts demands a creative and intelligent view of the data, an effort most likely tackled within the realm of Visualization. These approaches to teaching require an instructor that often acts more as a guide or assistant, than a conveyor of knowledge.

Visualization requires substantial computing power and memory, typically high bandwidth, and a user interested and knowledgeable in the content related to the map, advanced skills in the use of a GIS, and detailed knowledge of cartographic and design principles. In nearly every case, Visualization is an independent effort, where a student searches for patterns in a highly interactive, personal manner. Visualization activities are approximated in module eight.

**Closing**

As complexity within the stages of the GIS framework increase, a more divergent, open-ended style of teaching and learning is demanded. While Presentation and Exploration support a rather didactic teaching approach, Synthesis and Visualization require highly skilled students engaged in a rich, dynamic research-based study. These levels would fit well with a project based learning instructional approach. The properties can be associated with each GIS stage are related to the cognitive levels of Bloom's taxonomy. Understanding and identifying various stages in the process framework is the first step in identifying and matching instruction while introducing GIS concepts in classroom teaching practices.

**Bibliography**

Baker, T.R. (2000). Introducing GIS in the classroom: A process framework. Available on http://kangis.org/ed_docs/process.pdf [January 2002].

MacEachren, A.M. 1994. Visualization in modern cartography: Setting the agenda. In *Visualization in modern cartography*, ed. A.M.MacEachren and D.R. Taylor. pgs. 1-12. Oxford: Pergamon Press.

McCormick, B.H., DeFanti, T.A., & Brown, M.D. (1987). Visualization in scientific computing. *Computer Graphics 21*(6).

Slocum, T.A. 1999. *Thematic Cartography and Visualization.* Upper Saddle River, NJ: Prentice Hall.

WestEd. nd. *DLRN Technology Resource Guide, Chapter 4*. [WWW online] DLRN Technology Resource Guide, Chapter 4.