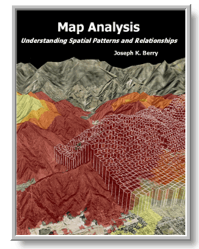
Beyond Mapping III

Topic 4: Where Is GIS Education?



***Map Analysis* book with companion CD-ROM for hands-on exercises and further reading**

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******For more on GIS Education, see* ***Education, Vocation and GIS Enlightenment****, 6th Annual IMAGINE Forum, Lansing, Michigan, May 1-2, 1997. Plenary address by J. K. Berry at* **www.innovativegis.com/basis/present/imagine97/**

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Where Is GIS Education

(GeoWorld, June 1997, pg. 30-31)

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GIS means different things to different people. To some, it is a tool that extends mapping to the masses. It allows the construction of custom maps from any desktop. It enables the spatially challenged to electronically locate themselves on a map, request the optimal path to their next destination, as well as checking the prices of motels along the way.

When coupled with a cell phone, they can call for help and their rescuers will triangulate on the signal and deliver a gallon of gas and an extra large pizza within the hour. Whether you are a lost explorer near the edge of the earth or soul-searching on your Harley, finding yourself has never been easier—the revolution of the digital map is firmly in place.

A new-age real estate agent can search the local multiple listing for suitable houses, then electronically "post" them to a map of the city. A few more mouse-clicks allows a prospective buyer to take a video tour of the homes and, through a GPS-linked handy-cam movie, take a drive around the neighborhood. A quick geo-query of the spatially-linked database, locates neighboring shopping centers, churches, schools and parks. The city's zoning map, land use plan and proposed developments can be superimposed for a glimpse of future impacts. Demographic summaries by census tracts can be generated and financial information for "comparables" can be plotted and cross-linked for a better understanding market dynamics. Armed with this information narrowing the housing choices, a prospective buyer can "hit the ground running" right off the airplane—the revolution of spatial database management is here.

However, the "intellectual glue" supporting such Orwellian mapping and management applications of GIS technology is still being fought in series of small skirmishes on campuses throughout the world. In part, the battles reflect the distribution of costs and benefits of the new discipline. From one perspective, GIS is viewed as a money pit draining the life-blood of traditional programs. It appears as an insatiable beast (like the plant's constant cry of "MORE!" in the Little Shop of Horrors) devouring whole computer labs with its gigabyte appetite and top-end taste in peripherals. The previous assault on "real computing" by the demeaning distractions of word processing, spreadsheets, and graphics packages pales by comparison. The insertion of yet another "techno-science" addition to the already burgeoning curricula appears to be the last straw. GIS's insidious tentacles are tugging at every department.

The classical administrator's response is to stifle the profusion of autonomous GIS labs and centralize them into a single "center of excellence." On the surface, this idea is not without merit. Its obvious economies of scale and orderly confines, however, often are met head-on by the savage realities of academic ownership. A GIS oversight committee composed of faculty from across campus often is an organizational oddity in a sea of established departments and colleges. Strong leadership within the committee is viewed as a "power-play" by the activist for his or her department and is quickly countered with the sub-committee kiss of death. Keep in mind the old adage that "the fighting at universities is so fierce, because the stakes are so small." Acquisition of space and equipment are viewed less as a communal good, as they are viewed as one department's evil triumph over the others. My nine years as an associate dean hasn't embittered me, as much as it has ingrained organizational realities. Bruises and scar tissue suggest that the efficiencies and cost savings of a centralized approach to GIS (be it academic or corporate) are largely lost to organizational entropy, user detachment and a lack of perceived ownership.

As with other aspects of campus life, GIS technology might benefit more from its diversity than from its oneness, with a single academic expression sized to fit all. If GIS is to become a fabric of society and spatial reasoning a matter of fact, its tangible expression as a divorced edifice on the other side of campus is dysfunctional. To be embraced and incorporated into existing courses, it needs to be as close to its users' hearts and minds as the door across the hall. An intellectual osmosis easily flows through the semi-permeable walls of a small departmental GIS lab. A well-endowed GIS center makes great publicity photos, but its practical access by faculty and students often rivals an assault on Bastille, guarded by unfamiliar and intimidating GIS-perts.

Assuming a balance can be met between efficiency and effectiveness of its logistical trappings, the issue of what GIS is (and isn't) still remains. Some of the earlier responses defined it as a mapping science, therefore it became the domain of the geography/cartography unit on campus. Other responses emphasized its computer and database underpinnings and placed it in the computer science department. More current definitions, however, spring from a multitude of applications in diverse departments, such as natural resources, land planning, engineering, business and health sciences.

The result is a patchwork of GIS definitions aligning with the separate discipline perceptions of its varied applications. This situation is both good and bad. It provides a context and case studies which resonate among selected sets of students. Unlike those introductory courses in statistics addressing the probability of selecting "a white or a black ball from an urn" (get real), application-specific GIS grabs a student's attention by directly relating it to his or her field of interest.

The underlying theory and broader scope of the technology, however, can be lost in the practical translation. While geodetic datum and map projections might dominate one course (map-centric), sequential query language and operating system procedures may dominate another (data-centric). A third, application-oriented course likely skims both theoretical bases (the sponge cake framework), then quickly moves to its directed applications (the icing).

While academicians argue their relative positions in seeking the "universal truth in GIS," the eclectic set of courses on campus becomes its tangible, de facto definition. It's at this level that a center of excellence in GIS is warranted—operating as a forum for exchange of ideas and expertise, not as a room full of hard and software items. Constructive discourse on what GIS is (and isn't) can be focused on the paradigms, procedures and people involved, rather than the trappings of the technology and whether "*dis'course is better than dat'course*" for the typical student.

Varied Applications Drive GIS Perspectives

(GeoWorld, August 1997, pg. 28)

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Our struggles in defining GIS revolve less around its mapping and management concerns, than its application contexts and expressions. Although there are variations in data structures, a myriad of geo-referencing possibilities, and a host of methods to derive thematic mapping intervals, it is GIS's modeling component that causes most of the confusion and heated debates of what GIS is (and isn't).

We have been mapping and managing spatial data for a long time. The earliest systems involved file cabinets of information which were linked to maps on the wall through shoe leather. An early "database-entry, geo-search" of these data required a user to sort through the folders, identify the ones of interest, then locate their corresponding features on the map on the wall. If a map of the parcels were needed, a clear transparency and tracing skills were called into play.

A "map-entry, geo-search" reversed the process, requiring the user to identify the parcels of interest on the map, then walk to the cabinets to locate the corresponding folders and type-up a summary report. The mapping and data management capabilities of GIS technology certainly has expedited this process and has saved considerable shoe leather… but come to think of it, it hasn't fundamentally changed the process. GIS's mapping and management components are a result of a technological evolution, whereas its modeling component is a revolution in our perception of geographic space and spatial relationships.

This new perspective of spatial data is destined to change our paradigm of map analysis, as much as it changes our procedures. **GIS modeling** can be defined as the representation of relationships within and among mapped data (see figure 1). A geo-query, such as "all counties with a population over 1,000,000 and a median income greater than $25,000" is not a GIS model. It simply repackages and plots existing data that describe independent map entities. Modeling, on the other hand, derives entirely new information based on spatial relationships, such as coincidence statistics, proximity, connectivity and the arrangement of map features.

As depicted in figure 1, GIS modeling can take several forms. The two basic approaches concern cartographic and spatial models. Whereas **cartographic modeling** involves the automation of manual map analysis techniques, **spatial modeling** involves the expression of numerical relationships of mapped data. The former treats numbers comprising a digital map as simply surrogates for traditional analog map representations of inked lines, colors, patterns and symbols. The latter anoints digital maps with all of the rights, privileges and responsibilities of quantitative data, thereby forming a new map-ematical discipline.

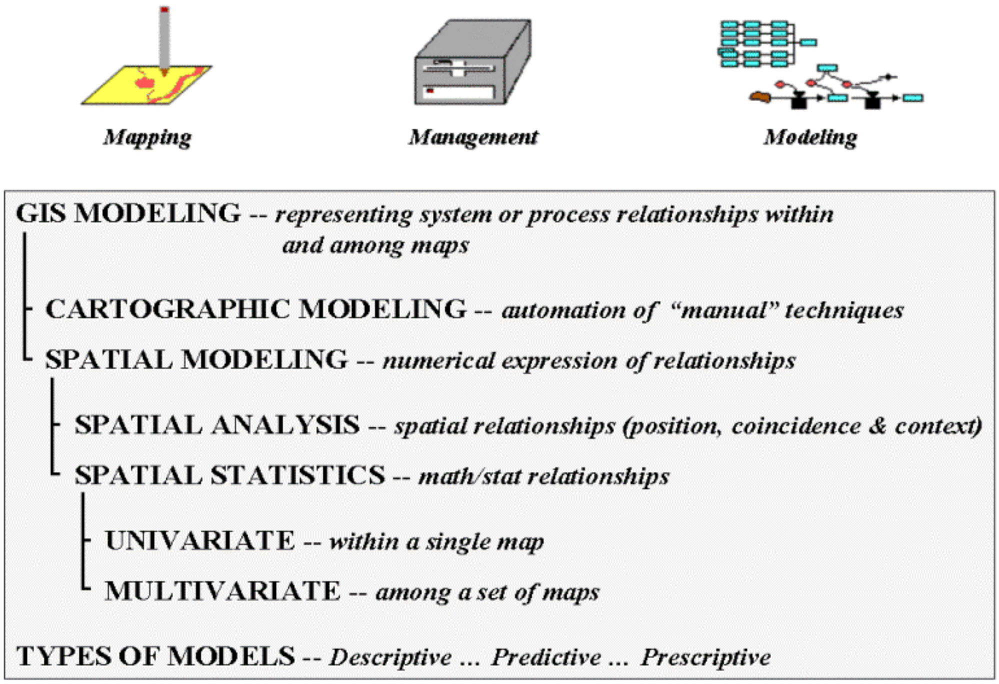

Figure 1. Various approaches used in GIS modeling.

The numerical treatment of maps, in turn, takes two basic forms—spatial statistics and spatial analysis. Broadly defined, **spatial statistics** involves statistical relationships characterizing geographic space in both descriptive and predictive terms. A familiar example is spatial interpolation of point data into map surfaces, such as weather station readings into maps of temperature and barometric pressure. Less familiar applications might use data clustering techniques to delineate areas of similar vegetative cover, soil conditions and terrain configuration characteristics for ecological modeling. Or, in a similar fashion, clusters of comparable demographics, housing prices and proximity to roads might be used in retail siting models.

Spatial analysis, on the other hand, involves characterizing spatial relationships based on relative positioning within geographic space. Buffering and topological overlay are familiar examples. Effective distance, optimal path(s), visual connectivity and landscape variability analyses are less familiar examples. As with spatial statistics, spatial analysis can be based on relationships within a single map (univariate), or among sets of maps (multivariate). As with all new disciplines, the various types of GIS modeling are not dichotomous, but identify the range of possibilities along a continuum of approaches. In addition, most applications utilize a combination of mapping, management and various types of modeling approaches in their solution.

In all cases, GIS applications involve spatial reasoning of complex systems, be they geo-business, ecological, or other processes. The GIS toolbox remains the same, however the applications dramatically change. These similarities and differences drive our varied perspectives of GIS technology and provide a framework for discussion of the paradigms, procedures and people GIS education needs to address… but discussion of the mix needs to be postponed to next time.

Diverse Student Needs Must Drive GIS Education

(GeoWorld, September 1997, pg. 30-31)

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GIS technology is "as different as it is similar" to traditional mapping and data analysis. Likewise, GIS education needs to incorporate unconventional concepts and approaches, as well as extending conventional ones—"business as usual" is out of the question. The diverse set perspectives of GIS technology provides a useful framework for discussion of GIS education, as it relates to paradigms, procedures and people.

Fundamental to understanding GIS is the recognition that a computer map is a set numbers first, a picture later. How the data is encoded and stored is important, as well as an appreciation of geographic principles, such as coordinate systems and map projections, particularly for students emphasizing database development and production mapping. A basic understanding of computer environments and operating as well as database management skills, such as indexing, selection ladders, and macro language proficiency, are important, particularly for students emphasizing management and modeling of spatial data. These, and similar topics, represent extensions of exiting concepts of space and data analysis, adjusted for the digital mapping environment.

Several concepts, however, represent radical shifts in the spatial paradigm. Take the concept of map scale. It's a cornerstone to traditional mapping, but it doesn't even exist in a GIS. Map scale reports the "ratio of map distance to ground distance," assuming a specific map output product. In a GIS you can zoom in and out on a particular area, changing its "scale" at will—map scale isn't part of the GIS, but an artifact of the screen or paper display. However, the related concept of map resolution is fundamental to GIS as it identifies the level of detail (spatial, thematic, temporal and mapping) captured in a digital map. Just as it is a violation to superimpose paper maps of differing map scales, it is a violation to superimpose digital maps of varying resolutions—both cases result in pure, dense (but colorful) gibberish.

Similarly, combining maps with different data types, such as multiplying the ordinal numbers on one map times the interval numbers on another, is map-ematical suicide. Or evaluating a linear regression model using mapped variables expressed as logarithmic values, such as a PH for soil acidity. Or consider overlaying five fairly accurate maps (good data in) whose uncertainty and error propagation results in large areas of erroneous combinations (garbage out). It is imperative that GIS education fully embraces the quantitative aspects of maps and instills an understanding of its implications beyond the inked line and paper map paradigm.

The practicalities of implementing procedures often overshadow their realities. For instance, it's easy to use a ruler to measure distances, but its measurements are practically useless. The assumption that everything moves in a straight line does not square with real-world—"as the crow flies," in reality, rarely follows a straightedge. Within a GIS, distance (shortest straight line between two points) can be extended to proximity (by relaxing "between two points" to "among sets of points"), then to movement respecting relative and absolute barriers to travel (by relaxing "straight line" to "not-necessarily-straight route").

In practice, a 100 foot buffer around all streams is simple to establish (as well as conceptualize), but has minimal bearing on actual sediment and pollutant transport. It's common sense that locations along a stream that are steep, bare and highly erodeable should have a larger setback. A variable-width buffer respecting intervening conditions is more realistic.

Similarly, landscape fragmentation has been ignored in resource management. It's not that fragmentation is unimportant, but too difficult to assess until new GIS procedures emerged. Procedures, such as travel-time surfaces, *n-th* optimal path density, and data-surface modeling, are challenging old, limiting assumptions about spatial data and their relationships.

These new procedures and the paradigm shift are challenging GIS users and their educational needs. Potential users first can be grouped by their interaction with the technology, then by their situation. Three broad types of users can be identified: Application-centric (routine user, casual user and interactive user), Data-centric (data entry specialist, database manager, and system manager), Procedure-centric (software programmer and application developer). In turn, these user groups can be further refined by their disciplinary focus (natural resource, business, engineering, etc.).

The diversity of users, however, often is ignored in a quest for a "standard, core curriculum." In so doing, a casual user interested in geo-business applications is overwhelmed with data-centric minutia; while the database manager receives to little. Although a standard curriculum insures common exposure, its like forcing a caramel-chewy enthusiast to eat a whole box of assorted chocolates. The didactic, two-step educational approach (intro then next) is out-of-step with today's over-crowded schedules and the diversity GIS users. A case study approach with extensive hands-on experience provides better focus, but it puts a greater burden on individual instructors and facilities.

A potential user's situation has a bearing on GIS education. In the broadest sense there are two situations: traditional and non-traditional. The former group includes conventional students flowing through the K-12, undergraduate and graduate programs. In the long run, GIS exposure will appear throughout this pipeline. However, in the short run most students are frantically attempting to retrofit themselves. Traditional courses tuned to a methodical progression rarely fit their backgrounds and schedules (interests aside).

Although non-traditional students tend to be older and even less patient, they have a lot in common with the current wave of "out-of-step" traditional students. They have even less time and interest in semester-long "intro/next" course sequences. By default, vocational training sessions are substituted for their GIS education—"how to" replaces "what and why." The two estranged student groups, however, pose an interesting opportunity for partnering between industry and academia. The need for targeted short courses by both student groups suggests intensive offerings over weekends and vacation periods. The extended network of in-place instructional facilities provides the logistical setting, while collaboration between vendor and academic instructors provides the intellectual material.

A mixed audience of traditional and non-traditional students provides an engaging mixture of experiences. So what's wrong with this picture? What's missing? Not money as you might guess, but an end run around institutional inertia and rigid barriers. Adoption of GIS technology can't wait a generation for the normal flow through the educational pipeline. A "steady-she-goes" approach of the institutionalized education tanker needs turning… or have we missed the boat entirely?

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Author's Note: *the first three sections of this series on GIS education is based on a plenary presentation made to the Sixth Annual MAGINE Forum, May 1 and 2, 1997, Lancing, Michigan*.

Turning GIS Education on Its Head

(GeoWorld, May 2003, pg. 20-21)

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Now that GIS is in its forth decade, some of the early mystery has been diminished. Simply displaying a map on a computer a few years ago was Herculean feat. Automatically hot-linking your vacation pictures to their exact location on map and having Aunt Julie in Winnemucca view them over the Internet wasn't even on the radar screen.

As much as its technological underpinnings have changed, GIS's learning environment and academic approaches seems to have evolved even more. In the 1970s, the mainframe computer kept students at least one glass window away from the machine and simply getting the proper "job control" sequence of punch-cards was a challenge. The 1980s ushered in interactive computing but the intellectual exchange has severely burdened by the din of competing systems, procedures, concepts and ideologies. GIS was maturing but still very much in its adolescence stage.

In the 1990s several factors converged—sort of a perfect storm for GIS education.

Cantankerous workstations morphed into user-friendly PCs with power, GPS technology put direct access of "where" information literally in users' hands, data became ubiquitous via the Internet, and most importantly, GIS software emerged from its specialist's cocoon.

The early environments kept GIS in a backroom "down the hall and to the right." Its modern expression, however, enables users with increasingly diverse backgrounds to take the wheel. The splash of digital maps on the screens in the front offices are radically changing what spatial technology is (and isn't), who constitutes the GIS community and how educational curricula address this evolution.

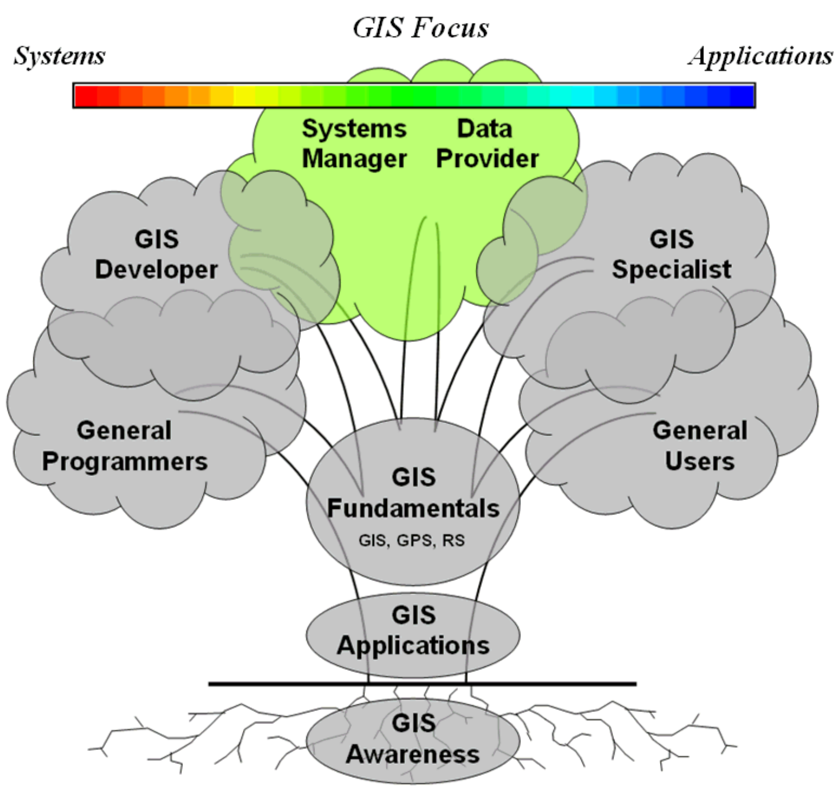

Figure 1. The GIS community encompasses a rapidly growing number of disciplines and diverse perspectives of what spatial technology is and isn't.

Figure 1 characterizes the GIS community as a tree with branches representing different activists. The left side membership is primarily focused on system design and development, while the right side emphasizes applications. To be fully effective, GIS curricula must recognize the increasingly diffuse character of the student pool and offer courses tailored to a variety of interests.

For example, the perspectives, skill sets and GIS goals of *General Users* are fundamentally different from those of *General Programmers.* In addition, the student pools likely reside in different subcultures on campus that rarely share a classroom.

Spatial technology can serve as a common thread but the course work requires recognition of diverse backgrounds, interests and objectives.

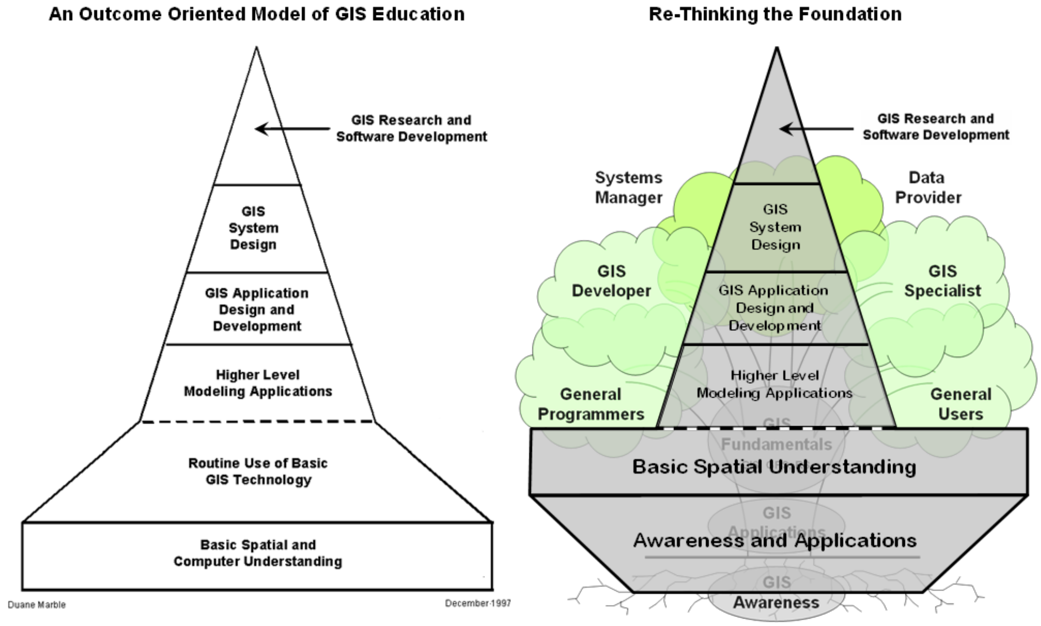

Figure 2. GIS education traditionally proceeds from basic spatial concepts and routine use through advanced applications and system design/development (after Marble, 1987).

Professor Marble with Ohio State University is a leading GIS educator who sees the situation from a slightly different angle (see Figure 2 and Author's Note). He identifies a pyramid with progressive levels of spatial skills and is concerned about the "…the great majority of persons who are 'educated' in GIS attaining competence only at the very lowest operational level." In addition, he sees minimal attention "…being paid in most programs to the education of individuals who desire to reach the higher levels of the pyramid."

These points are very well taken and reflect the evolution of most disciplines crossing the chasm from start-up science to a popular technology. Marble suggests the solution "…appears to be to devise a rigorous yet useful first course that will provide a sound initial foundation for individuals who want to learn GIS and that also makes extensive use of GIS technology in its presentation." At the same time he recognizes that "…if we tell people that they cannot 'do' GIS without first taking several courses then I suspect they will simply ignore us."

So how can GIS education raise awareness and stimulate interest while instilling a sound foundation in the underlying concepts, procedures and considerations? It's at this point that my thoughts slightly diverge from Marble's. Whereas he is concerned with the "dilution of GIS education," I am just as concerned about generating awareness and stimulating new applications by casting the broadest net possible.

The right-side of figure 2 turns the early phases of GIS education on its head by suggesting that the "Basic Spatial" principles (e.g., geode, datum, projections, data/exchange, etc.) be presented after students are introduced to spatial reasoning concepts. This would mean that students are not initially confronted with mechanics, technical details and data principles but work with hands-on exercises that clearly illustrate and instill "thinking with maps."

Such experience wouldn't be a rice-cake flurry of "dog-and-pony show" applications (e.g., frog habitat modeling in Belize for geo-business students) but contain real-meat exercises using (and this is important) perfect data and procedures that demonstrate spatial concepts within student's own area of interest and expertise. While designing such materials is a piece-of-cake from a technical perspective, it means that the contextual structuring of the materials requires expertise outside of GIS.

That means that the next piece of the GIS education puzzle needs to come from a dispersed set of departments/colleges throughout campus— a sociologist here, a real estate professor there, an IT instructor around the corner (and the eye of newt if needed). The bottom line is that GIS-*perts* need to recognize that the field has grown beyond its original disciplinary boundaries.

The "up-side-down" approach suggests that the growing pool of potential new users are first introduced to what GIS can do for them and how it's different from traditional ways of doing things, then progress to the mechanics required for solo flights. GIS has grown-up and is rapidly becoming part of the fabric of society. Where and how far it is taken in the next decade will be determined, in large part, by an effective educational setting.

Author's Note*: See Marble, Duane F. 1997. Rebuilding the Top of the Pyramid: Structuring GIS Education to Effectively Support GIS Development and Geographic Research. Proceedings of the Third International Symposium on GIS and Higher Education [Online] Available at:*
http://www.ncgia.ucsb.edu/conf/gishe97/program_files/papers/marble/marble.html.

Author's Update*: (9/09) Duane Marble in a more recent thoughtful article entitled "Defining the Components of the Geospatial Workforce—Who Are We?" published in ArcNews, Winter 2005/2006, suggests that—*

"Presently, far too many academic programs concentrate on imparting only basic skills in the manipulation of existing GIS software to the near exclusion of problem identification and solving; mastery of analytic geospatial tools; and critical topics in the fields of computer science, mathematics and statistics, and information technology."
(http://www.esri.com/news/arcnews/winter0506articles/defining1of2.html)

This dichotomy of "tools" versus "science" is reminisce of the "-ists and -ologists" differing perspectives of geotechnology in the 1990's. For a discussion of this issue see Beyond Mapping III, Epilog, "Melding the Minds of the "-ists" and "-ologists." available at:
http://www.innovativegis.com/basis/MapAnalysis/MA_Epilog/MA_Epilog.htm#Melding_Minds.

Other related postings are at:

- http://www.innovativegis.com/basis/present/GIS_Rockies09/GISTR09_Panel.pdf, handout for the panel on "*GIS Career Opportunities*," GIS in the Rockies, Loveland, Colorado; September 16-18, 2009.
- http://www.innovativegis.com/basis/present/LocationIntelligence09/LocationIntelligence09.pdf , handout for the panel on "*Geospatial Jobs and the 2009 Economy*," Location Intelligence Conference, Denver, Colorado, October 5-7, 2009.

– http://www.innovativegis.com/basis/present/imagine97/, a keynote address on "*Education, Vocation and Enlightenment,*" IMAGINE Forum, Lansing, Michigan, May 1997.

A Quick Peek Outside GIS's Disciplinary Cave

(GeoWorld, January 2010)

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Over the past few months I have had the opportunity to participate in several panels discussing the future directions of geotechnology, with particular emphasis on career outlook and GIS education (see Author's Notes). One particularly intriguing "broad-brush" question setting the stage was "*What are the most radical changes that we have seen in geotechnology's evolution and that we will likely see in its future?"*

In contemplating the question I realized that it wasn't until the late 1990s that I fully realized the impact of the "perfect geotechnology storm" brought on by the convergence of four critical enabling technologies; 1) the personal computers' dramatic increase in computing power, 2) the maturation of GPS and RS (remote sensing) technologies, 3) a ubiquitous Internet and 4) the general availability of digital mapped data. If any one of these elements were missing, the current state of geotechnology would be radically different and most certainly not as robust or generally accepted. Much of our advancement, particularly of late, has come from external forces. And now that we are "in the limelight," more and more of our evolution will be influenced by non-specialists' (vis., the GIS unwashed) and their perspectives on what maps are and how they might be used.

In the early years, GIS was "down the hall and to the right," sequestered in a relatively small room populated by specialists. Users would rap on the door and say "Joe sent me for some maps." Today, geotechnology is on everyone's desk and in nearly everyone's pocket. Contrary to most GIS perspectives, our contributions have been as much a reaction to enabling technologies and outside influences as it has been proactive in the wild ride to mass adoption.

Keep in mind that geotechnology is in its fourth decade—

- the 1970s saw *Computer Mapping* automate the drafting process through the introduction of the digital map;
- the 80s saw *Spatial Database Management* link digital maps to descriptive records;
- the 90s saw the maturation of *Map Analysis and Modeling* capabilities that moved mapped data to effective information by investigating spatial relationships; and finally,
- our current decade focuses on *Multimedia Mapping* emphasizing data delivery through Internet proliferation of data portals and advanced display mechanisms involving 3D visualization and virtual reality environments, such as in Google and Virtual Earths.

The future of our status as a "mega-technology" alongside the giants of biotechnology and nanotechnology will be in large part self-determined …that is, if we step out of the specialist's closet and fully engage other disciplines and domain experts. The "era of maps as data" (Where is What?) is rapidly giving way to the "age of spatial information" where mapped data and analytical tools directly support decision-making (Why, So What and What If?). The direct relevance of geotechnology isn't just a wall hanging, it's an active part of the consideration of geographic space; whether it's a personal "what should we do and where should we go?" decision on a vacation, or a professional one for locating a pipeline, identifying wildlife management units or establishing a marketing plan for a new territory.

The key for developing successful solutions beyond data delivery lies in domain expertise as much, if not more, than mapping know-how. The geometrical increase in awareness and use of geotechnology by the masses will lead to entirely new and innovative applications that we haven't even dreamed of (nor can we dream of them in a geotechnology silo). The only way we could drop the ball is to retreat further into our disciplinary cave.

On a technical front, I see a radical change in geo-referencing from our 400 year reliance on Cartesian "squares" in 2-D and "cubes" in 3-D to hexagons (2-D) and dodecahedrals (3-D) that will lead to entirely new analytic capabilities and modeling applications (see Author's Notes). To conceptualize the difference, imagine a regular square grid morphing into a grid of hexagons like a tray in a bee hive. The sharp corners of the squares are knocked-off resulting the same distance from the centroid to each of the sides defining the cell …a single consistent step instead of two different types of steps (diagonal and orthogonal) when moving to an adjacent location. Now consider a three-dimensional world with 12-sided volume (dodecahedral) replacing a cube …a single consistent step instead of a series of differing steps to all of the surrounding locations.

This seemingly slight shift in spatial theory, however, will revolutionize our concept of geographic space. At a minimum, it finally will dispel the false assumption that the earth is flat …at least in our traditional map world that stacks two-dimensional map layers like pancakes. At a maximum, it will enable us to conceptualize, analyze and actualize spatial conditions within a fully three-dimensional representation of the real world. Then all that we will need to do is to figure out a way to fully account for time, as well as space, in our maps for a temporally dynamic representation of geography—but that's another story to be written by tomorrow's geotechnologists.

Another important trend reshaping geotechnology is its move toward commoditization. Commoditization implies *the transformation of goods and services into a commodity thus becoming an undifferentiated product characterized solely by its price, rather than its quality and features*. The product is perceived as the same no matter who produces it, such as petroleum, notebook paper, or wheat. Non-commodity products, such as televisions, on the other hand, have many levels of quality. And, the better a TV is perceived to be, the higher its value and the more it will cost.

So where is geotechnology along this commoditization continuum? Like the other two mega-technologies (*bio*- and *nano*-) it has a split personality with both commodity and non-commodity characteristics. In our beginning, research dominated and the mere drafting of a map by a plotter was perceived as a near miracle in the 1970s. Fast forward to today and digital maps are as commonplace as they are ubiquitous—a transformation from "knock-your-socks-off" to commodity status (and maybe "old dirty socks" that ought to be avoided in a decade or so of 3D GIS technical advancements).

But we shouldn't confuse mass adoption of a map product or service with commoditization of an entire technology. It is like the product life cycle in pharmaceuticals from trials, to unique flagship drug, to generic forms and finally to commodity status. While the products might cycle to commodity, industries don't as long as innovation keeps adding value and new product lines.

What is rapidly becoming a commodity in our field is generic mapped data and Internet delivery. However, contemporary value-added products and services are extremely differentiated; such as a propensity map for product sales, a map of wildfire risk, and a real-time helicopter routing map that avoids enemy detection. The transition is a reflection of a paradigm shift from mapped data to spatial information—less of a focus on automating traditional mapping roles and procedures, to an emphasis on new ways of integrating spatial relationships into decision-making ...*thinking with maps*.

The bottom line is that commoditization of geotechnology is neither good nor bad, nor an advantage or disadvantage. It just is a natural progression of product life cycles and renewed advancements in value-added features and services through continued innovation. If we fail to innovate, the entire industry will become commoditized and GIS specialists will hawk their gigabytes of graphics in the geotechnology commodity market next to the wheat exchange in Chicago.

The career take-home is that an individual can't assume one brush with a four-year smart pill in education is sufficient. An individual's ability to go beyond traditional mapping is the key— from a focus on management, access, display and geo-query of spatial data (*Descriptive Mapping* that is more "data-centric") to an enlarged focus on integration of enterprise data, value-added processing and applications of spatial information (*Prescriptive Mapping* that is more "application-centric"). The discussion in the next section investigates some of the pitfalls along the geotechnology career path and education alleyways.

Author's Notes: *Summaries of the career/education panels are posted at* www.innovativegis.com/basis/basis/cv_berry.htm#KeyNote. *See the online book Beyond Mapping III at www.innovativegis.com/basis/MapAnalysis/, Introduction, "Referencing the Future" and Topic 27, "GIS Evolution and Future Trends."*

GIS Education's Need for "Hitchhikers"

(GeoWorld, February 2010)

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The last section addressed a "broad-brush" panel question on "*What are the most radical changes that we have seen in geotechnology's evolution, and that we will likely see in the future?*" The discussion invoked an assessment of the four-decade trajectory of GIS, both in terms of its driving forces and incremental capabilities and utilities.

Another very basic question that seems to be making the circuit is "*Where do we go from here? …and how do we make it happen?*" As background, one needs to realize that we have established the basic means of encoding, analyzing, visualizing and storing geographic information, and have the prerequisite computer power to digest it all. In addition, we have maturing standards and a huge quantity of mapped data content in terms of vector and image data—lock and load, but what is the target?

To many, the future target is a giant leap beyond mapping and spatial record-keeping to full integration of geotechnology into real world decision-making processes— from land management to building design to retail marketing to environmental protection and a myriad of other applications. While I am sure there are technical waypoints along the path we take from here, the human element likely will be the most critical factor of forward progress, with a revamping of the education component leading the way.

It's interesting to note that our earliest tinkering with GIS had a huge tent with zealots from all disciplines tossing something into the stone soup of an emerging technology— foresters, engineers, geographers, epidemiologists, hydrologists, farmers, geologists to mention but a few. As the field matured the big tent's diversity contracted considerably as "specialists" emerged and formal programs of study and certification surfaced.

There are many positive aspects in this maturation, but there also are some drawbacks. In many universities, a GIS Center of Excellence emerged and lodged in a disciplinary stovepipe of a single college or department. In addition, the maturation of the field resulted in a "one shoe fits all" curriculum with focus on training tomorrow's GIS'ers.

But this educational footing is far too limited for a leap from mapping to modeling. The breadth of potential applications suggests that geotechnology is ill served as the special domain of any discipline, or even coalescence into a discipline unto itself. A continuum of diverse activists have and are shaping geotechnology's future— from those "of the computer," such as *Computer Programmers*, *Solutions Developers*, and *Systems Managers*, to those more "of the application," such as *Data Providers*, *GIS Specialists*, and *General Users* (figure 1).

Historically, digital mapping tilted toward the right side of the continuum as GIS specialists established and nurtured vast databases that automated existing business practices. Then map analysis and modeling shifted focus toward the left side with Solution Developers doing the heavy lifting by providing new capabilities, models and turnkey solutions.

Of the Computer	… ← Continuum of Focus within Geotechnology → …				Of the Application
Computer Programmer	Solutions Developer	Systems Manager	Data Provider	GIS Specialist	*General User*
…develops GIS tools; …mostly computer science skills with some experience in GIS	*…develops applications that link GIS to real-world problems; …mostly GIS/CS background with some discipline expertise*	*…develops and maintains spatial databases and connections within (LAN) and outside (Internet) the organization; …CS and GIS balance*	*…develops GIS databases; …good skills in GPS and remote sensing with strong skills in GIS data formats and geodetic referencing*	*…interacts with other GIS professionals and users to implement spatial solutions; …GIS with considerable discipline expertise*	*…applies GIS operations, techniques, procedures and models to address real world processes in support of decision-making; …strong discipline expertise with GIS awareness*

Figure 1. The continuum of the GIS community reaches from computer science development to a mosaic of general user applications.

However, the "bookends" of this continuum are the current drivers. Increasingly, computer science and technological advancements in visualization and access are at the frontier. With the full embrace of RS, GPS and GIS by Google, Oracle and other "big-hitters" in the computer industry, geotechnology's applications are becoming ubiquitous.

It is hard to pick up a magazine, watch TV or attend a conference that new and powerful ways of accessing and interacting with mapped data aren't being ballyhooed—my grandmother would be proud. For first time society comprehends a paperless map and marvels at its uses, from saving lives with OnStar to finding a store across town to zooming in to a beach in Belize. While geotechnology is at the foundation, it has been applied computer industries that hit the ball out of the park.

It is widely purported that eighty percent of all data has a spatial component but simply "mapping to visualize" these data is rarely sufficient in many decision-making arenas. Geotechnology's next leap forward will be lead by the other bookend group—involving the active participation of domain experts in development of entirely new applications addressing complex spatial relationships. The old adage that "those with the problems have the solutions" apply applies.

As long as the questions involved "*how do I map that?*" or "*where is what?*" GIS'ers at the core of the continuum could take the lead. But as questions progress to "*why and so what?*" and "*do what where?*" the solutions move well beyond mapping—to spatial reasoning, dialog and problem solving.

Within a modeling context, disciplinary knowledge of underlying concepts, assumptions, state variables, driving variables, processes, rates and limits becomes paramount. In most fields, understanding of these relationships has been developed through years of non-spatial science. The idea that spatial considerations could be "addressed spatially" is foreign—"shouldn't all that data be collapsed to a mean and standard deviation?" The notion that there are tools for characterizing geographic distributions and relationships within and among mapped data has been outside their experience base, and all too often outside their comfort zone.

But domain expertise is the key ingredient for innovative solutions of complex spatial problems. The direct engagement of bright minds with a practical understanding of the dimensions and complexities of a potential application has been the "missing link." In large part, a "campus chasm" that is too onerous for most students to cross proves to be the barrier.

Contributing to the divide is that the preponderance of geotechnology education focuses on "discrete spatial objects" as a set map features composed of Points, Lines and Polygons (**Vector** perspective). However, most spatial models focus on "continuous spatial distributions" of geo-registered map variables expressed as gradient Surfaces (**Raster** perspective) with all of the rights, privileges and responsibilities of a true "map-*ematics*."

This requires a paradigm shift from our current thinking of what GIS is and isn't— from a mapping focus (warehousing, accessing and visualizing mapped data) to an application focus (solving spatial problems). This involves a conceptual shift, not just a structural change. For many GIS'ers the thought is a bit outside their experience but for non-GIS'ers it is a totally foreign and "off-the-wall" perspective of a map.

In an earlier section ("*Turning GIS on Its Head*," GeoWorld, May 2003; see Author's Note) discussion suggested that the traditional didactic approach of "fundamentals first, then applications" severely limits the breadth of exposure of geotechnology across campus. While a "*data-centric* mindset" that geotechnology education starts with geographic/cartographic principles and proceeds through software mechanics works for the inner core players along the GIS continuum, it effectively excludes the bulk of the bookend players.

An alternative is an introductory experience where students interact with the mapping and modeling capabilities at the onset without knowledge of mapping "details," such as geodes, datum and projections. Within this context, the early focus is shifted to a grasp of the problem solving capabilities of geotechnology— an "*application-centric* education."   Toward the end of the experience the mapping details can be introduced within the context of accuracy and precision assessment, rather than establishing a set of working skills required in the mechanics of database development and maintenance.

Ideally, this experience aligns with students disciplinary interests. As with other aspects of campus life, geotechnology can benefit more from its diversity than from its oneness. It's often perceived condition as a divorced discipline for specialists on the other side of campus has dramatically hindered geotechnology from reaching its full potential as a fabric of society, and spatial reasoning as a matter of fact.

To accomplish this transition we need to engage applied "domain expertise" in GIS offerings.   This means that outreach across campus as important (and quite possibly more important) than honing courses for training core professionals. This perspective suggests less flagship/toolbox software systems and more custom/tailored packages solving well-defined spatial problems that stimulate "thinking with maps." The next section will investigate approaches and procedures that can be used to move beyond the perception that GIS is a cluster of technical specialists "down the hall and to the right" to a collaborative team of domain experts and GIS specialists solving real world spatial problems.

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Author's Notes: *A more detailed discussion of the need to infuse spatial reasoning into non-GIS curricula is posted online at http://www.innovativegis.com/basis/MapAnalysis/Topic4/Topic4.htm#Turning_GIS_education, "Turning GIS Education on Its Head," Beyond Mapping column, GeoWorld, May 2003.*

Fitting Square Pegs into Round GIS Educational Holes

(GeoWorld, March 2010)

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Last section suggested that geotechnology needs "hitchhikers" to reach beyond mapping. The technology's first three decades capitalized on the development of the digital map, first simply for *Computer Mapping*, then for *Spatial Database Management* and then for *Map Analysis* by exploiting entirely new encoding, storage, processing and display tool sets that were radically different from our paper map legacy (figure 1).

Through the 1990's, the new kid on the block, *Geographic Information Systems and Science*, was in the driver seat and in control of the emerging technology.   However with the new millennium, geotechnology matured into a mega-technology that captured the full attention of the computer industry and its reading of the huge potential market for *Multimedia Mapping and Visualization*. The result was near commoditization of many traditional digital mapping capabilities—tremendous mass acceptance and use occurred, but innovation shifted from the GIS community core toward the computer science bookend.

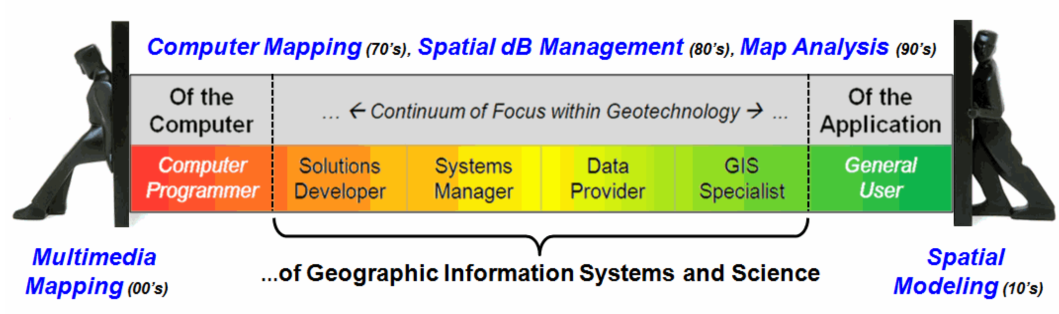


Figure 1. The bookends of the continuum of the GIS community are the current drivers of Geotechnology.

Looking forward into the next decade two dominant thrusts seem to be surfacing. While the bulk of the GIS community will continue to develop and expand the digital map repository, a small group of innovators will work with computer scientists to radically revolutionize our current data and processing structures. A somewhat larger contingency will engage general and innovative users in developing *Spatial Models* that integrate domain expertise, spatial reasoning and map analysis tools in support of solutions and decision-making.

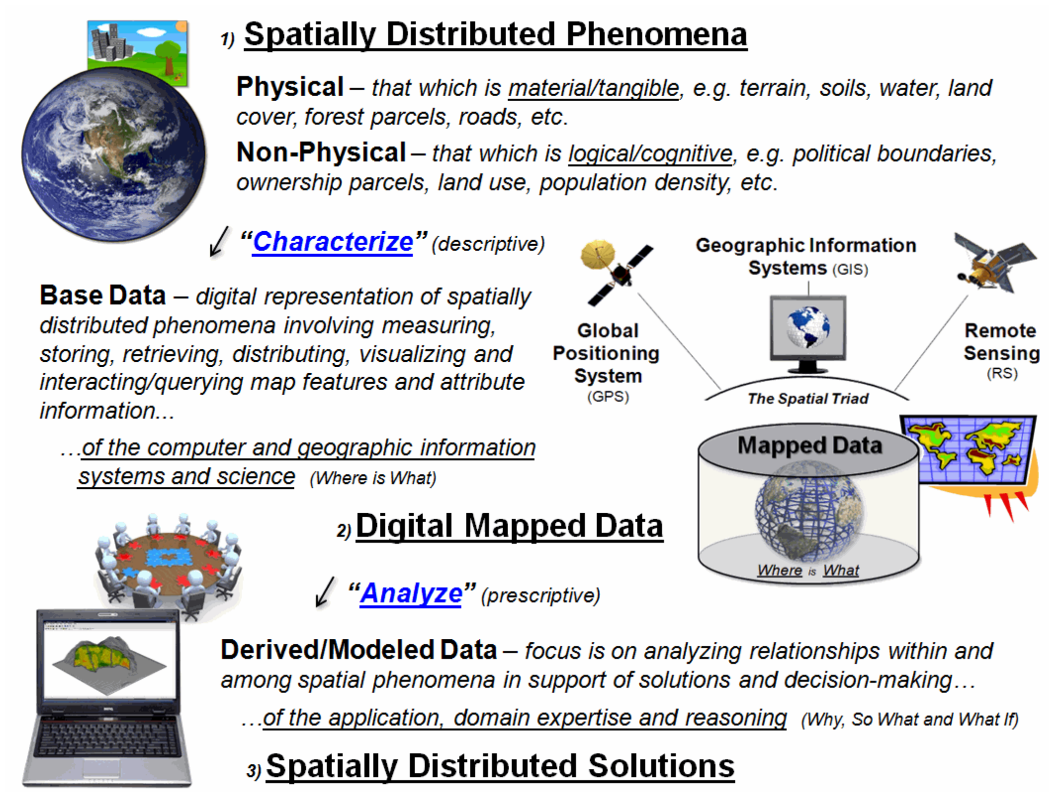


Figure 2. Map analysis and modeling extend mapped data to spatial solutions.

Figure 2 depicts the major components involved in spatial modeling. Historically, maps focused on precise placement of physical features (material/tangible) primarily for navigation. As mapping evolved more non-physical information (logical/cognitive) found its way into map form. In the past few decades both types of descriptive characterizations of spatial phenomena have been incorporated into huge digital mapped data repositories identifying "Where is What" with sophisticated tools for interacting with the data.

The step from digital map data to spatially distributed solutions involves a paradigm shift from descriptive "Where is What" mapping to prescriptive "Why, So What and What If" modeling. This transition in emphasis involves the other bookend (users) as much, or more, than it involves the core GIS community. It suggests that spatial reasoning needed for the transition lies outside the usual knowledge, skill sets and experience of GIS'ers. However, most GIS curricula are designed to service the core community with minimal attention to reaching other disciplines—they can take our established courses, but targeted courses for non-GIS'ers focusing on spatial problem identification and solving are rare indeed.

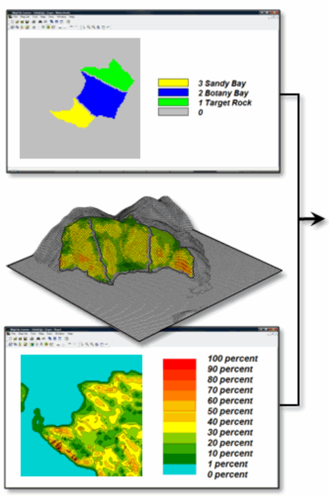
Yet the development of curricula and courses for the "unwashed" likely will determine geotechnology's future. If we are to reclaim a share of driver's seat we need to instill closer and active relationships with the bookends of the GIS community. The small group of technology innovators seems well along the way through research initiatives and industry investments.

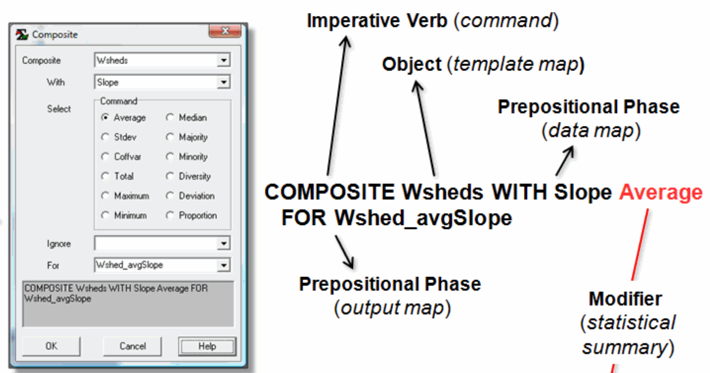
The knurly problem lies in engaging a dispersed set of applied disciplines to develop awareness and skills in spatial reasoning. The old adage "they don't know what they don't know" applies and over-stuffed disciplinary curricula keeps most students at bay. What elective "holes" are available are usually tied-up by concentration tracks that delve even deeper into their discipline. This, coupled with a university administrative structure that struggles with inter-disciplinary efforts, effectively limits exposure of most students to spatial reasoning and problem solving.

Two potential remedies to this disciplinary stovepipe "standoff" seem viable—both requiring the initiative of the geotechnology academic community. First, a concerted "outreach" program needs to be developed where GIS students are encouraged to develop a secondary disciplinary thrust that focuses on spatial problem solving instead of the usual database compilation concentration. In addition, faculty needs to develop secondary ties across campus that actively contribute to teaching and research involving spatial reasoning within applied disciplines.

An important step in this outreach is recognizing that the GIS tool isn't the focus and "training" outside students/faculty in the nuances and fine distinctions of database construction and GIS software isn't relevant. The objective becomes developing an awareness of the capabilities of GIS through instructive case studies coupled with simple hands-on exercises.

Hands-on experience is critical but it can't be the same as for traditional GIS students. Flowcharts provide a mechanism for interacting with a spatial model's logic and its processing expression (e.g., ArcGIS's Model Builder). The link between step-by-step logic of a model and the sequencing of the commands becomes the objective. For example, figure 3 uses MapCalc Learner (see Author's Note) to decipher a region-wide overlay summary that derives the average slope within three watersheds. Note that the command forms a complete grammatically correct sentence that resonates with less-technical students and that the contextual help provides information on additional summary options providing fodder for further discussion.





Statistic	Target Rock	Botany Bay	Sandy Bay	Discussion
Min	9.0	0.0	10.0	*Minimum slope value within the watershed.*
Max	58.0	50.0	63.0	*Maximum slope value within the watershed.*
Median	33.0	25.0	36.0	*Value midway in the distribution of slope values--half above, half below; a measure of the "typical" slope.*
Average	32.9	36.0	32.3	*Arithmetic mean defined as the sum of all values divided by the number of values; a measure of the "typical" slope; if the median and average are significantly different, the data is said to be non-normal.*
Stdev	11.0	9.3	9.4	*Describes the dispersion spread of data around the average; a measure of "how typical" the average is.*
Coffar	28.7	33.9	34.1	*Ratio of the standard deviation divided by the average expressed as a percent; larger values indicate more variation and in this example can be interpreted as rougher terrain.*
Deviation	-31.9	-25.4	-29.3	*Computes the average deviation of the individual slope values from the watershed average slope; larger values indicate more variation and in this example can be interpreted as rougher terrain.*

Region-Wide Statistics Table. *The region-wide statistics indicate that the Target Rock watershed is slightly steeper (Average= 32.9) and not as rough (Coffvar= 28.7) as the other two watersheds.*

Figure 3. Effective education for non-GIS students shifts the focuses from mapped data to interacting with model logic and its spatial reasoning foundation.

As GIS education moves beyond mapping the emphasis lies in full engagement of cross-campus entities. Like remora and the shark, a symbiotic relationship with applied disciplines is what will take us there.

Author's Note: *A listing of several MapCalc Learner "application exercises" used in special presentations for various applied disciplines are at www.innovativegis.com/basis/Senarios/Default.html#Application_examples. The educational software system can be downloaded for free.*

Which Direction Are You Headed?

(GeoWorld, January 2011)

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In another section (see Author's Note), I commented on using the more generalized and palatable term *Geotechnology* to describe what some of us over time have referred to as Automated Cartography, Computer Mapping, Geographic Information Systems, Spatial Database Management, Desktop Mapping, Geospatial Technology, Geomatics, Map Analysis, Multimedia Mapping and a wealth of other terms.

The discussion identified the *Spatial Triad* of Remote Sensing (RS), Geographic Information Systems (GIS) and Global Positioning Systems (GPS) as core technologies that "utilize spatial location in visualizing, measuring, storing, retrieving, mapping and analyzing features or phenomena that occur on, below or above the earth." While RS and GPS seem to have fairly succinct and universal meanings, the definition of GIS has sparked continuing debate. Most will agree on something like GIS is "a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data." But what is the interpretation the acronym itself?

My first encounter in the acrimonious acronym dispute was in the mid-1970s when the "G" in GIS was under scrutiny. The early GIS folks on the west side of the Atlantic were convinced it stood for "geograph<u>ic</u>," while those on the eastern side insisted it stood for "geograph<u>ical</u>." A quick Google search yields a boat load of discussion forums still hammering on the grammatical debate. It appears that it boils down to that the "…*ic*" in geographic means "of or pertaining to geography," whereas the "…*cal*" in geographical means "of geographic"—there seems to be more style than substance in the debate, as both terms are adjectives.

The "I" in the GIS acronym seems to be accepted by all as "meaning or pertaining to information." The important point to be made here is that <u>data</u> are simply facts without context. When data are processed, organized and structured within a given context to make them useful, they become <u>information</u>. This is a significant distinction to keep in mind as we tackle the different perspectives and interpretations of the trailing "S" in GIS.

It is the "S" that carries considerable conceptual, as well as grammatical baggage. Early debate focused on whether it meant "system (singular)" or "systems (plural)." The sides at the time seemed to align with whether one had a comprehensive turnkey commercial system, or cobbled together a bunch of public domain software packages. With the advent of today's specialized apps, mash-ups, cloud computing and the like, it seems that the "S" might be shifting back toward the plural and away from a flagship system paradigm.

Figure 1 takes the debate beyond the grammatical by outlining different substantive interpretations of the trailing "S" that greatly impacts GIS education, career planning, on-the-job skills and depth/breadth of understanding of spatial concepts, procedures and applications. The figure intentionally uses the intermediary compass positions (officially termed "intercardinal or ordinal") of NE, SE, SW and NW as a nod to astute geographers and as an indication that that the categorization blends fairly rigid "near cardinal" viewpoints.

At the birth of the discipline, the "S" unequivocally stood for the hardware, software and dataware with little or no reference to people or use—simply ***GISystems***. In this early stage (1970s) the focus was on just cobbling together a system that could handle digital maps without crashing. The dream might have been boundless utility but the practical reality was whether maps as numbers was a viable concept and could be shoehorned into the tinkertoy computing environments of the day.

Today, the GISystems perspective still holds that the GIS enabling mechanisms are paramount. Like the pit crew in a NASCAR race, GIS can't go anywhere without a finely tuned and fueled computing environment. However, over the years the "systems" interpretation has expanded to GISpecialist, GIScience, and GISolutions that primarily respond to differing perspectives on the data versus information distinction.

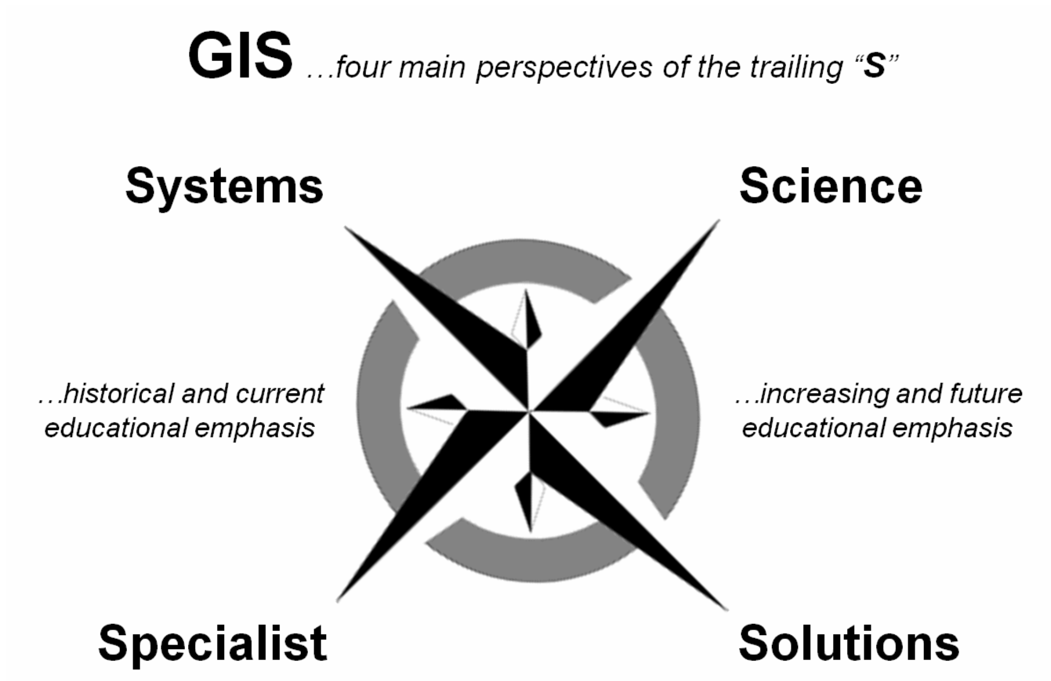

Figure 1. Four perspectives on the trailing "S" in GIS.

The idea that the trailing "S" defines ***GISpecialist*** took hold in the 1990s as the result of two major forces—uniqueness and utility. As GIS shifted from the "Eureka, it's alive" perspective of the early GIS innovators to an operational systems outlook, the uniqueness of different application environments became apparent. Enterprise systems sprung up and needed specialists who understood the unique character of an organization's spatial data and could serve as in-house experts in its care, feeding and use. By enlarge the GISpecialist's role was that of a "down the hall and to the right" resource that field, managerial and executive folks could tap when they needed maps and spatial information.

Numerous certificate and certification programs were designed to produce the needed specialists. At the same time a ***GIScience*** perspective took hold that recognized a more in-depth discipline was coalescing and would serve full undergraduate and graduate degrees in geotechnology. The GISpecialist has evolved into a "practitioner" role (what does it take to keep a GIS alive and how can it be used?) while the GIScience perspective tends more toward the "theoretical" (how does GIS work, how could it be improved and what else could it do?).

A fledgling ***GISolutions*** perspective has been around for some time, but seems to be capturing a lot more attention. Early GIS solutions focused on mapping and geo-query that primarily automated existing business practices. Cost and time savings in maintaining and accessing mapped data were at the heart of these highly successful applications.

However as digital mapped data became more available, interest turned to how the paper-map-based practices might be enhanced to improve operations and decision-making. Today, the focus seems to be on entirely new GIS applications from iPhone crowdsourcing to Google Earth visualizations of real-time spatial information to advanced map-ematical models predicting wildfire behavior, customer propensity to buy a product and optimal routing of a powerline.

The "GI" (Geographic Information) component seems to be a universal root, but the trailing "S" has evolved through differences in perspective of what GIS is and isn't. The GISystems and GISpecialist roles form the foundation of geotechnology's contemporary expressions whereas the GIScience and GISolutions roles determine its future directions.

Author's Note: *For a discussion on Geotechnology as an encompassing term, see Beyond Mapping III, Introduction, "What's In a Name?" posted at www.innovativegis.com/basis/MapAnalysis/MA_Intro/MA_Intro.htm#Name).*

Questioning GIS in Higher Education

(GeoWorld, June 2012)

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Recently I had the opportunity to sit on a panel concerned with "GIS in Higher Education: Simultaneously Trivializing and Complicating GIS" (see author note 1). In about an hour of interactive discussion we only addressed a couple of the planed questions. Below are thoughts and notes from the ones we discussed and initial thoughts on those we didn't get to.

Question: Is there an <u>*inherent responsibility*</u> *for the GIS community in higher education to further general awareness and understanding of geotechnology (RS, GIS, GPS) across campus? If so,* <u>*in what ways*</u> *can we provide opportunities for non-GIS faculty and students to learn about GIS capabilities as a "technology tool" and as an "analysis tool" considering interdisciplinary education constraints and considerations (e.g., budget, organization, time, promotion/career considerations, etc.)?*

[Note: during the break prior to the panel, I sketched the "technical tool" versus "analytical tool" trajectory on the whiteboard (figure 1)]. The use of GIS as a "technical tool" has skyrocketed, while its use as an "analytical tool" has relatively stalled over the past decade.

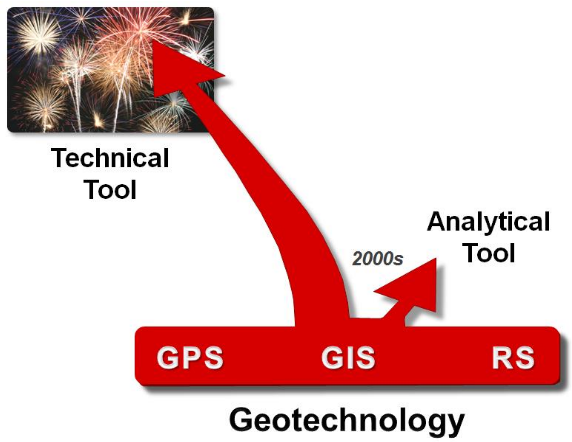

Figure 1. During the past decade GIS as a "technical tool" has skyrocketed, while its use as an "analytical tool" has relatively stalled.

In the current euphoria of GIS as a "technical tool," the marketplace is defining not only what GIS is, but its future. To some degree, higher education in GIS on many campuses seems to have abdicated a primary leadership role and tend to have taken a "vocational role" focusing on training GIS-specialists.

To most folks on campus, geotechnology is simply a set of highly useful apps on their smart phone or a 3D fly-by anywhere in the world— in a sense <u>trivializing GIS</u>. To a smaller contingent on campus, it is career path that requires mastery of the mechanics, procedures and buttons of extremely complex commercial software— in a sense <u>complicating GIS</u>.

Any new or rapidly evolving technology has an inherent responsibility to further general awareness of the full potential of the technology. The technical tool's mapping, display and navigation capabilities seem to be easily learned through vender promotion and peer pride "look at what this can do" instruction.

However the radical nature of the "analytical tool" perspective drastically changes how we perceive and infuse spatial information and reasoning into science, policy formation and decision-making— in essence, how we can "think with maps" for solving complex spatial problems. To achieve our billing as one of the three mega-technologies of the 21st century (Bio-, Nano- and Geotechnology) we need to 1) insure that spatial reasoning skills are taught K12 through higher education, 2) instill the idea that modern digital maps are "numbers first, pictures later" and 3) these organized sets of numbers support quantitative analysis.

I am increasingly struck by the thought that we are miss-communicating GIS's potential, particularly with the science communities on campus who ought to be excited about infusing spatial considerations into their research and teaching. The result is that innovation and creativity in spatial problem solving are being held hostage to 1) a trivial mindset of maps as pictures, 2) an unsettling feeling that GIS software is too complex, and 3) a persistent legacy of a non-spatial mathematics that presupposes spatial data can be collapsed to a single central-tendency value that ignores any spatial variability inherent in the data.

The most critical step in providing opportunities that further general awareness and understanding across campus is to recognize the inherent responsibility of non-GIS student education, as well as traditional GIS specialists. Specific actions might include—

- Encourage seminars demonstrating applications,
- Establish a networking organization encompassing all interested disciplines,
- Teach a class or lab for a department outside of your own,
- Organize or team-teach a discipline-oriented workshop with a domain expert,
- Write proposals for non-GIS teaching, research and outreach,
- Solicit VP-level administers' support for integrated efforts, and
- Consider adopting a *Spatial*STEM approach that translates grid-based map analysis operations into a mathematical/statistical framework that serves as the communal language of science, technology, engineering and mathematics disciplines (see author note 2).

OK, that's my Pollyanna perspective …what's the chance that an enlarged view of GIS education will ever take root on your campus? …what would it take?

Question: What are the <u>similarities and differences</u> between <u>GIS and non-GIS students</u> (e.g., background, interests, time, career aspirations) and what similarities and differences are there in <u>structuring course content and "hands-on" experiences</u> (e.g., formal class, workshops, seminars)?

My experience is that non-GIS students are less interested in the mechanics of GIS and more interested in how GIS might be applied in their field to solve problems. For the past few years I have had considerable proportions of students outside of Geography/GIS in my graduate course in GIS Modeling at the University of Denver (see author note 3) with more outside students than inside this past term, as well as two qualified undergrads. These students know little about traditional GIS concepts (geodes, coordinates, projections, data structures, cartography, etc.) but in most cases a lot about quantitative methods for analyzing data.

I use an easy-to-learn grid-based software package (MapCalc Learner, see author note 4) in the course that students load onto their personal computers along with the databases used in the weekly homework assignments. The 3-hour class meeting is consumed with lecture and discussion (no formal lab sessions). The students work in 2-3 person teams on their own and are expected to complete the homework assignment as a professional report (format, spelling, grammar, composition are graded) with discussion and appropriate screen grabs of their results—more problem-solving than lab exercise.

I believe several "characteristics" of non-GIS students can be identified—
- Interested in applying GIS to solve problems in their field,
- Rarely to mildly interested in becoming GIS-specialists,
- Want to know the basic concepts, procedures, considerations and limitations of the technology,
- Focused on the utility of GIS to them (minimally interested in RS or GPS),
- Concerned about the practical aspects of GIS (e.g., software, data availability) , and
- Generally interested in the future directions of GIS.

I believe some fundamental "characteristics" in structuring an educational offering for non-GIS students (course, short course, workshop, guest lecture/lab or seminar) to consider are—
- Tailoring the presentation to the audience's interests, disciplinary background and current spatial problems is critical (GIS for GIS sake is unacceptable),
- Instructor "hands-on demonstrations" (or student hands-on exercises) are extremely valuable,
- Animated slides that sequence logical steps in developing a concept is preferable,
- Ample time/opportunity for discussion is important (Socratic questions as lead-in to topics are effective), and
- Links to online further readings/references are useful.

OK, that's my scar-tissue-based advice …what has been your experience(s) in presenting GIS to non-GIS folks? …what words of advice can you share?

Question: Given the advance and convergence of Citizen Science/Volunteered Geographic Information, mobile and easy-to-use geo-technologies, the open data movement, and cloud-based GIS, is everyone a geographer? Is everyone able to easily ramp into a GIS career?
- GIS as an interactive "technical tool" for map viewing, navigation and geo-query is for everyone (potentially billions of users; negligible skills required),
- Map making today primarily involves choosing a template and following a wizard's guidance from the cloud so just about anyone can be a map maker (millions; minimal skills),

– GIS as an "analytical tool" is for many individuals as they augment their domain expertise with spatial reasoning and problem-solving skills (millions; considerable skills), and
– GIS as a career is not for everyone (hundreds of thousands; considerable skills).

Question: How will <u>*cloud computing and interactive applications impact GIS education*</u> *both from a GIS-specialist and a GIS-user perspective?*
– For the GIS specialist they need a working knowledge of structuring online databases and interactive services/solutions in the cloud, and
– For the GIS user they will be free from flagship software demands and will be able to utilize very large data sets and services from the get-go, and
– Lat/Lon grid-based referencing will become a universal key for joining currently disparate data sets in the cloud.

Question: What does <u>*the GIS education community need to do*</u> *in the next 1 to 3 years to ensure that spatial analysis, geographic inquiry, and GIS are supported, taught, and* <u>*used throughout the educational system*</u>*?*
– Teach the teachers,
– Help construct tailored introductory lectures/labs for existing courses in other disciplines, and
– Develop/promote/offer courses for non-GIS students (ideally team-teach with domain expert).

Question: What <u>*types and levels of computer knowledge/expertise and quantitative methods will be required*</u> *for developing successful GIS applications and solutions?*
– We need to develop in our GIS students a better understanding of grid-based spatial stat/math operations and quantitative analysis methods,
– Instill skills in general-purpose, high-level programming languages, such as Python, for integrating systems and programs with GIS, and
– Instill skills that are needed for the production and maintenance of websites (web design and digital media studies).

Question: What <u>*factors are most limiting*</u> *to the continued development of GIS education on your campus (student interest, colleague backing, workload, promotion/tenure process, administration support, space, budget, etc.)?*
– Promotion and tenure doesn't fully recognize interdisciplinary efforts,
– Budgets for interdisciplinary courses and teaching are not readily available on most campuses, and
– Departmental workload does not provide time for efforts outside of the department.

The bottom line is that the GIS academic community has an intellectual and noble responsibility to educate non-GIS students in the full capabilities of geotechnology and how it is changing our paradigm of what maps are and how they can be used from a historical perspective of "Where is What" to a modern expression of "Why, So What and What If" within problem solving contexts. The rub is that there is minimal incentive, encouragement or support in turning the academic tanker— at this point a few charitable GIS'ing zealot professors are needed.

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Author's Notes: *1) GIS in Higher Education Symposium, Metro State College, Department of Geography, Denver, Colorado; April 6, 2012. 2) See* ***www.innovativegis.com/basis/Papers/Other/SpatialSTEM/SpatialSTEM_case.pdf****. 3) You can review all of the GIS Modeling course materials to include lecture PowerPoints, exercises, exams and MapCalc Learner software used at* ***www.innovativegis.com/basis/Courses/GMcourse12/****. 4) For more information on freely distributed MapCalc Learner, see* ***www.innovativegis.com/basis/****, select Software items.*

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