Closing Panel on Geospatial STEM

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Outline of Reposes to Panel Questions

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(Note: this white paper is posted at ***www.innovativegis.com/basis/Present/GeCo_West2013/Panel/GeospatialSTEM_panel.pdf****)*

Biosketch: *Joseph K. Berry* is *a leading consultant and educator in the application of Geographic Information Systems (GIS) technology. He is the author of the popular books Beyond Mapping, Spatial Reasoning and Map Analysis, author of the Beyond Mapping column for GeoWorld magazine for over twenty years, and written over two hundred papers on the theory and application of map analysis and modeling techniques. Since 1976, he has presented college courses and professional workshops on geospatial technology to thousands of individuals from a wide variety of disciplines. He holds a B.S. degree in forestry from the University of California, Berkeley, a M.S. in business management and a PhD emphasizing remote sensing and land use planning from Colorado State University.*

See **http://www.innovativegis.com/basis/basis/cv_berry.htm** for additional information about the panelist

General Statement: The K-12 grade levels have received the bulk of STEM attention, in general, and geospatial STEM in particular. Funding and curriculum development have focused on developing awareness of geospatial technology as a "technological tool" involving mapping and geo-query to facilitate access and useful display of existing spatial data. However, an opportunity exists at the college level for geospatial STEM to be utilized as an "analytical tool" in the investigation, interpretation and solution development. From a college level perspective, geospatial STEM education seeks to fully infuse understanding of the spatial distributions (as well as traditional numerical distributions) in quantitative data analysis of mapped data into research and professional applications. To effectively realize this goal, map analysis principles, procedures and practical experiences need to be tailored to STEM disciples and sensitive to specific domain interests, backgrounds and expertise—simply accepting students from across campus into existing "GIS Specialist" courses is not a viable geospatial STEM option. Two major paradigm shifts are necessary to fully engage "spatial reasoning" at the college level: 1) the GIS community needs to recognize and embrace **quantitative analysis of maps is a reality**; and 2) the STEM community needs to recognize and embrace **spatial relationships exist and are quantifiable**. A grid-based math/stat framework for GIS's existing analytical capabilities can serve as the glue that binds the two perspectives—a common, coherent and comprehensive approach that compliments and extends traditional math/stat operations into the spatial realm.

For further discussion, see
"Where Is GIS Education?" at **http://www.innovativegis.com/basis/MapAnalysis/Topic4/Topic4.htm**
"A Math/Stat Framework for Map Analysis" at **http://www.innovativegis.com/basis/MapAnalysis/Topic30/Topic30.htm**

Potential Questions:

1) *Geospatial aside, how do each of you view recent STEM initiatives in the United States?* …in a nutshell, the efforts are uncoordinated and generally ineffective. A quick search of the Internet reveals that there are over a dozen federal agencies that run hundreds of different STEM programs not considering separate state and local initiatives. And despite spending nearly $3 billion annually on STEM education, America still ranks 25th in math and 17th in science when compared to other countries. In general, I concur with Bruce Alberts' (Editor of Science) lament that "we are simultaneously trivializing and complicating" science education (*http://www.sciencemag.org/content/335/6066/263.summary*). On one hand, a large portion of science education has evolved (devolved?) into a game of Trivial Pursuits with "factoids" and Mr. Wizard-like theatrics as the focus. On the other hand, students emphasizing science are increasingly confronted by daunting course workloads and stringent prerequisite requirements. A middle ground focusing on conceptual understanding and practical experience of the "big picture" of basic theory, practices and realistic utility of the STEM disciplines seems to be, for the most part, missing.
   See http://www.usnews.com/topics/subjects/stem_education links to several US News and World Report articles on STEM education

   a) K-12 activities? …early STEM education efforts have received the most attention and experienced the greatest results. In part, this might be the result of 1) the general nature of the material itself (e.g., "why is the sky blue"; "what causes earthquakes"; "etc.) and 2) the disposition of the teachers (e.g., comfort level with basic science concepts and principles). As grade-levels become higher, the material becomes more complex and fewer teachers feel comfortable. By high school most science courses become increasingly specialized and demanding. As a result, the student pool tends to self-bifurcate into science versus non-science educational tracks that remain in place during their higher education experiences.

b) State Standards, National Standards (e.g. Wyoming science standards, NCGE geography standards). …"standards" can be as disruptive as they are helpful in STEM education. While they are useful in assessing a particular storehouse of knowledge and produce simple metrics for allocating funding, standards also tend to constrain and lock-in the material studied—a sort of "one size fits all education." As a result, class experience can become didactic with little room for exploring beyond the textbook by either the student or the teacher. Similarly, standards rarely consider knowledge gained by hands-on experience and independent study in an effective manner. Standardized curricula and testing can (and often?) dampen the enthusiasm and active engagement of students, particularly the brightest ones.

c) How is STEM in higher education different from K-12? …STEM education at the college level has two distinct components. Most of the formal STEM initiatives are directed at insuring a basic level of science, technology, engineering and math understanding across the general student population—sort of a last ditch effort to insure some degree of STEM understanding that will be critical to the nation as the world becomes increasingly technological. Significant strides have been made on most campuses, particularly in computer usage.

The other STEM education component involves strengthening, enlarging and advancing the curricula and student experiences within the STEM disciplines themselves. For the most part, it is assumed that the U.S. continues to be the leader in higher education in science-based fields as the continuing flood of graduate and post graduate applications from other countries remains high. However, basic B.S. degrees on most campuses seem less stellar than they did a few years ago. The increase in computer usage has removed a lot of the tedious and time consuming "busy work" but seems to be focus more on "what do I do" (mechanics) than on "what is happening" (theory) and "how can I apply new thinking to different situations" (reasoning). This is particularly apparent in the use of complex commercial software that often challenge students to "press the keys and click the mouse" in the proper sequence (vocation experiences) with less attention to what is happening and why it's important.

2) What is geospatial STEM education? …at one level, geospatial STEM involves creating <u>awareness</u> of the capabilities, potential applications and limitations of digital mapping, geo-query, map analysis and modeling. Starting at K-12 and continuing through undergraduate education it is imperative that students develop a practical proficiency with "apps and applications" involving RS, GPS and GIS technology. These technological tools have become commonplace in most workplaces from forestry and farming to powerlines and pipelines to marketing and medical industries. Even if geotechnology isn't an element of a professional career, a healthy awareness is needed for being an engaged citizen and personal well-being—it has become a "fabric of modern society" that is difficult to ignore.

At another level, development of <u>spatial reasoning skills</u> within the STEM disciplines themselves is needed to infuse consideration of the spatial distribution of data, as well as the numerical distribution traditionally considered in quantitative data analysis.

a) Who are the educational clients? …the range from building general spatial awareness to developing spatial reasoning skills encompasses just about all educators at all levels. For example—

*…an **elementary math teacher** might follow discussion in calculating the percent difference in corn production on a farmer's field between two years with "…but is that overall difference the same everywhere in the field? Where is the percent difference more? Where is it less? The spatial evaluation of the percent change equation (past minus current divided by past then times 100) does that by…" (you know the rest of the story).*
*…or a **high school math teacher** might follow a discussion of the Pythagorean Theorem with "…but what if there is an impassible barrier between the two points? The distance is no longer a straight line but some sort of a 'bendy-twisty' route around the barrier. How would you calculate the not-necessarily-straight distance? The 'Splash Algorithm' does that by…" (you know the rest of the story).*

At the college level it is imperative that the STEM disciplines actively embrace geotechnology directly into their teaching and research. For example,

*…a **statistics instructor** might follow a lecture on the derivation of the Standard Normal Curve for characterizing the ‘numerical distribution’ of a data set with “…but what about the ‘spatial distribution’ of the data? Is data always uniform or randomly distributed in geographic space? How could you characterize/visualize the spatial distribution? ‘Spatial Interpolation’ does that by…” (you know the rest of the story).*
*…or an **environmental science professor** might follow a lecture on the use of riparian buffers with “…but are all ‘buffer-feet the same’? What about the slope of the surrounding terrain? …and the type of soil? …and the density of vegetation? Wouldn’t an area along a stream that is steep with an unstable soil and minimal vegetation require a much larger setback than an area that is flat with stable soils and dense vegetation? How could you create a variable-width buffer around streams that considers the intervening erosion conditions? A simple ‘sediment loading model does that by…” (you know the rest of the story).*

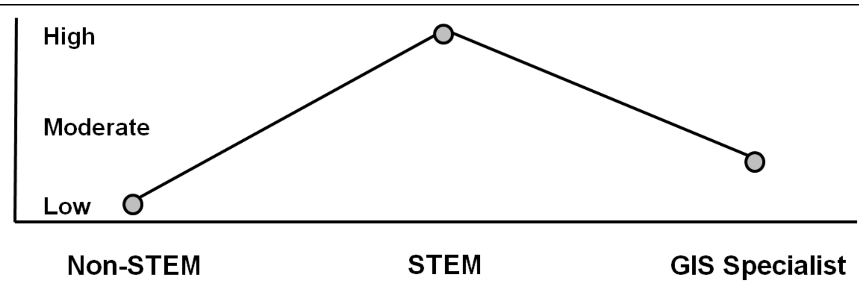
The idea that “GIS is down the hall and to the right” existing as an isolated group of mapping specialists is no longer valid. Geotechnology specialists and system managers are needed to “acquire and maintain” mapped data, but increasingly the “processing and analysis” require domain expertise. Traditional GIS courses designed to develop geotechnology skills (of the technology) are inappropriate for STEM students interested in applying the technology (of the application).

Discussion of Spatial STEM can be confusing because there are several very different situations, expressions and paradigms at play. Discussion of Spatial STEM can be confusing because there are several very different situations, expressions, experience sets and paradigms at play. The graphic below attempts to group these different perspectives into nine panels based on *Student Focus* and *Grade Level*—

		Student Focus		
		Non-STEM	**STEM**	**GIS Specialist**
Grade Level	**Elementary Schools**	Basic Awareness	—	—
	Junior High and High School	Basic Awareness	*Basic Aptitude and some Skill Development*	—
	College *(Associate, Undergrad, graduate)*	Basic Awareness and **Application Appreciation**	*Skill Development in **Map Analysis/Modeling***	*Proficiency, Competence in **RS/GIS/GPS***

Level of Proficiency in Traditional Quantitative Data Analysis

(Math/Stat)



When discussing Spatial STEM education, it is important to identify which panels are reflected in statements of experience and recommendations. Most of my responses relate to college level education directed to all three student focus categories. In my opinion, the *Geographic Information Science and Technology Body of Knowledge* and the *Geospatial Technology Competency Model* efforts have, for the most part, focused on skill development for the GIS Specialist at the college level. It would be interesting to identify what material in these guidelines is germane to Spatial STEM education and what instructional approaches are most effective in communicating this information to the other panels in the graphic.

3) *Within the general educational field, who cares (or should care) about infusing geospatial technology into their classroom?* …teachers at all levels and in just about all disciplines should be interested in incorporating some aspects of the geosciences into their courses. As a new thread in the fabric of society it affects the ecological, environmental, economic, political, legal, ethical, social, cultural and even spiritual welfare of peoples everywhere. Geotechnology, as one of the three mega-technologies for the 21st Century (bio- and nano-technology are the others), is posed to alter society as much as it assists—it is far more important than simply a faster and more colorful mapping technology.

a) Are educators supportive of this? …some are and some aren't. By enlarge teachers are more receptive to new ideas and programs than administrators. By its very nature, modern geotechnology cuts across disciplines and therefore isn't easily corralled into a single disciplinary silo. Straddling disciplines presents considerable budgetary and accounting problems, particularly at the college level. In its early years as a mapping science geotechnology was easily housed in the college/department on campus that was most involved with mapping (e.g., geography, natural resources, landscape planning, civil engineering). In its broader role involving STEM and other disciplines on campus, a more appropriate administrative home might be at the university level (e.g., library, institute, interdisciplinary program) that encourages the widest acceptance and discourages "circling the wagons" around one perspective of what GIS is (and isn't).

b) How might this level of interest change in the next ten years? …I suspect the educational interest in geotechnology will increase dramatically in ten years. The availability of of inexpensive and easy-to-use teaching materials and targeted "hands-on" exercises/applications are critical to increased interest. Established sets of educational resources will enable teachers to incorporate spatially-based lessons into their existing courses without being forced to become GIS-perts.

For example, business students will no longer have to endure studying a "tree frog habitat" model to learn about suitability modeling as they did in the early 1990s. Rather, they will interactively tweak a "spatial propensity to buy" marketing model to investigate its sensitivity of customer habitat to various demographic, economic and lifestyle factors—likely applied locally. Two conditions are poised to help; 1) an ever-increasing wealth of mapped data is becoming available, and 2) GIS capabilities are becoming part of standard database and statistical software. Grid-based data will fuel the fire of adoption as it easily "walks" between GIS systems (as geo-registered *matrices*) and database systems (as geo-registered *fields*).

4) *How are the geospatial STEM goals, methods and logistics different / similar at the grade school, high school and college levels?* …the general awareness and introductory goals, methods and logistical aspects of SpatialSTEM are fairly similar at all levels of teaching—create an appreciation for "thinking spatially." To a large extent, technological progress is greasing the skids. Not so long ago, a lab that put a GPS unit and digital camera in a student's hands was revolutionary. Now that GPS unit and camera is integrated into the smart phone in their back pockets and with a couple clicks the image is posted to the Internet. Technological "wow" seems to morph to "duh" in a blink of the eye. Keeping the "wow" interest of the general student body in geotechnology necessitates expensive cutting-edge technology and constant retooling.

An alternative is to demonstrate cutting-edge applications that demonstrate the profound impact geotechnology is having on how we perceive, process, and utilize spatial information in understanding and solving complex problems… less "shock and awe" and more targeted application tied to current curriculum is needed.

However, SpatialSTEM for STEM students (particularly at the college level) is radically different. The twist is that SpatialSTEM in this case is not just a platform to broadcast and gain greater awareness for geotechnology on campus, but actually a <u>canonical new perspective on quantitative data analysis</u> (at least for most STEM professionals) that should become a valuable arrow in the quiver of all STEM students…

- Grid-based map analysis and modeling provides an extension to current non-spatial statistics and spatially aggregated models that ignore information in spatial patterns and relationships.
- Analyzing the spatial distribution of data is as important as analyzing the numerical distribution.
- Understanding the contextual and numerical character inherent in mapped data supports new solutions.
- The "answers" from grid-based map analysis and modeling are spatially distributed so management solutions can do one thing here and different things over there instead of applying an aggregated typical solution everywhere.
- Big data seems to be the future of quantitative data analysis and data doesn't get much bigger than mapped data.

What we (GIS communities) need to do is engage the STEM disciplines on their turf—quantitative data analysis—instead of continually demonstrating the technological wonders of modern mapping, Internet access, real-time navigation and awesome displays. These wonders are tremendously important and commercially viable aspects of geotechnology, but do not go to the core of the STEM disciplines.

5) *What is the best balance of "vocational/training" for developing practical skills versus "educational/theory" for instilling conceptual understanding?* …practical skills development is needed by students who consider themselves "of the technology," whereas a conceptual understanding is needed by students who consider themselves "of the application." The historical legacy of GIS systems is one of a complex, nuanced and often cantankerous beast few students wanted to wrestle. Today, entry points like Bing Maps, Google Earth, spatial data blades and related apps make working with mapped data much easier for the end user. Like an auto mechanic, GIS specialists will always be needed to keep robust databases available, but it is the end user that drives successful solutions.

a) How does the balance shift for different types of students and grade levels? …at the lower grade levels and general student pools, the vocational aspects of geotechnology needs to be minimal. The primary objective is to demonstrate the wide-ranging utility of geotechnology. In this environment it is important that the experience is "hands-on" and closely tied to the current class topic/curriculum. An isolated geotechnology dog-and-pony show experience can diminish the educational opportunity.

At the higher grade levels more keyboard mechanics and fundamental principles can come into play to explain "how geotechnology works." However, the details are light for a <u>general student</u> (a car has an engine, drive train and chassis to make it go; a map has geo-registered values that locate conditions/characteristics on the earth's surface); more detailed for the <u>STEM student</u> (an engine has a cylinder, spark plugs, values, pistons, connecting rods and crankshaft that provides the kinetic energy to move a car; a grid-based map layer is a matrix of values with the column positions representing Longitude (X direction) and row positions representing Latitude (Y direction); and most detailed for the <u>GIS specialist</u> (the value clearance, or lash, between the tip of the rocker arm and the value stem tip must be adjusted to the lash setting that comes with the cam shaft; Longitude and Latitude coordinates are determined by the oblate spheroid shape established by geodetic mathematics through equations that account the earth's gravity and rotation).

6) *How well does the GIS&T Body of Knowledge (e.g., NCGIA Core Curriculum) address geospatial STEM education?* …in its current form the GIS&T Body of Knowledge poorly address geospatial STEM education as it primarily was developed by GIS'ers for GIS'ers to guide GIS vocational/training aspects in educating GIS specialists. To drive a new BMW one doesn't need to study Bernoulli's flow equations and turbocharger design. The GIS&T Body of Knowledge needs to be reworked to eliminate "superfluous" detail (from a STEM end user's perspective) and provide more experience in map analysis, modeling and application development.

a) What aspects, if any, do you think could be tailored to better address geospatial STEM education? …most college level STEM students are interested in understanding and relating relationships among driving variables to advance knowledge (basic research) and solve problems (applied research). This suggests <u>less emphasis on vector-based approaches</u> involving collections of "discrete map features" for geoquery of existing map data and <u>more emphasis on grid-based approaches</u> involving surface gradients of "continuous map variables" for investigating relationships and patterns within and among map layers.

b) What aspects, if any, do you think ought to be eliminated for geospatial STEM oriented education? …SpatialSTEM education (for both the general student body and most STEM students) should minimize the detailed aspects of mapping but retain the big picture concepts. For example, Lon/Lat coordinates represent a grid overlaid on a fairly precise representation of a spheroid that best represents sea level throughout the globe—like blowing-up a balloon to best fit the earth's surface. In a typical personal computer, the Lon/Lat resolution of the inscribed grid is about a four-inch square for most of the earth. The discussion of map projections might be constrained to noting that they involve translation of Lon/Lat earth positions (3D space) to a flat plane representation (2D space) and that there are a bunch of different projection equations. The take home for end users is that they must be careful not to mix maps with different projections of their area of interest; but good software will flag and correct on-the-fly projection differences.

7) *In higher education, how is geospatial STEM education different / similar to traditional geospatial education—in content, logistics, and classroom settings?* …for effective SpatialSTEM education the emphasis is shifted from the perspective of a provider of map data to that of the end users. First four decades of geotechnology focused on the development of the technology— a nascent area of study then. However, future decades will see geotechnology go mainstream by focusing on its applications.

a) How are the potential “outside” student populations different / similar to traditional geospatial students? …most general student body and STEM students are not interested in becoming GIS specialists or pursuing a career in geotechnology. They see it as an important piece to the expanding puzzle of their chosen field of study. A good academic analogy is statistics. There is a relatively small but vibrant cluster of folks in statistics departments around the globe working to advance the science; but there is a much larger number of statisticians working in public and private organizations in developing new applications; and there is a huge number of scientists and professionals directly applying statistical procedures to their data. I see a similar future for geotechnology where the “outside” student populations far outnumber the traditional geospatial students. The question is will existing GIS centers (viz. stat departments) service these students or will discipline-oriented courses be the norm (viz. business statistics, statistics for agriculture, natural resources statistics). The current “circle-the-wagons” mindset of GIS expertise on many campuses likely will spawn the latter outcome.

8) *In higher education, what are the relative advantages / disadvantages to offering geospatial STEM oriented courses versus embedding geospatial STEM experience into existing disciplinary courses?* …embedding SpatialSTEM experiences in existing courses is best for awareness and introductory experiences in geotechnology. Stand alone SpatialSTEM courses are appropriate for college level STEM students but it is imperative that they are tailored to the discipline and not general courses in the technology. While my experience has been that the mix of graduate students from a wide variety of disciplines is stimulating and students often learn best from each other, <u>course sizes of self-selecting students are too small to effect the radical change in STEM education that is needed</u>. Enthusiastic buy-in by the STEM disciplines from both teachers and administrators is the ticket.

a) What are the hurdles (departmental “stovepipes,” faculty mindsets, university administration, funding, lab space, etc.) to geospatial STEM's broader acceptance and support across campus? …by far the biggest hurdle at the college level is policy and administration. To achieve the level of scholarly recognition needed for P&T and salary bumps, it is prudent for faculty to laser focus on the current expressions of their disciplines. Arcing outside traditional bounds is generally an unhealthy condition for junior faculty—the very group that is most likely interested in SpatialSTEM innovation. The lip service for interdisciplinary efforts by university administrators tends to ring hollow at the college/department level. For geotechnology to become an important thread in the fabric of higher education, it must expand its impact beyond the care and feeding of GIS specialists.

But stepping outside disciplinary boundaries is unhealthy. This damned if you do, and damned if you don't condition most impedes a broader embrace of geotechnology by the STEM disciplines but I am convinced that it only delays the inevitable. It is inescapable that the incorporation of information about the spatial distribution of data along with its numerical distribution will surely overcome non-spatial statistics and spatially aggregated models …it's just when.

b) What are the incentives (team-teaching, supplemental pay, promotion & tenure recognition, etc.)? …at the college level the acceptance of geotechnology by STEM disciplines as an indispensible tool for quantitative data analysis is the most critical factor. To date most STEM disciplines see geotechnology as a faster and more colorful mapping technology, with minimal direct impact on what they do. The educational institutions that will move in front of the curve are those with strong leadership, particularly at the administrative level. Those institutions that have “geotechnology champions” at the highest levels will be defining GIS's future by parting the administrative, budgetary and policy waters to encourage team-teaching, supplemental pay, promotion & tenure recognition, etc.

At the K-12 level the incentives will be more traditional and come in the form of block grants, teacher training and potentially curricula requirements. In this scenario, policy makers and legislators become major agents of change. Since geotechnology moved into the PC environment most schools have the means (equipment) and just need to work on the will (training). The GIS industry could be a big player in this movement if they fully recognize and embrace a bigger role for geotechnology beyond mapping.

9) *How can the geospatial workforce benefit from – and support STEM education initiatives?* Already there is an enormous demand for spatial data and facilitating apps—the “technological tool” role is skyrocketing. However the “analytical tool” role has seemingly flat lined. This is the current reality, but if we (GIS community) myopically focus on today's paradigm it will forestall an even bigger role for geotechnology in

SpatialSTEM education. Greater awareness and introductory appreciation of geotechnology (particularly at the lower grades) is an important first step. In many instances, a marginally GIS-savvy workforce is a boon as location aware devices are flooding most workplaces. The ability to work with these "smart things" that know where they are basic entry requirements that bump worker productivity.

But the real benefit (and reason to support) comes from a workforce that can spatially reason new solutions and apply geotechnology in creative ways. These folks need SpatialSTEM education opportunities that lift their eyes from the map display to a more thorough understanding of the spatial relationships ingrained in the mapped data. The real bang for the buck comes from doing old things in new ways and doing entirely new things.

a) Is this reflected in curricular models such as the Geospatial Technology Competency Model, or in professional certification requirements?   …not really (enough said).