Sleepwalking into the Future – The Case for Spatial Analysis Throughout Education

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Abstract

The use of Geographic Information Systems (GIS) in education around the world is a relatively recent phenomenon. Settled almost entirely since 1990, the landscape is marked by pedagogical and technological trailblazing by enterprising educators who have overcome numerous challenges to teach about GIS and teach with GIS. They do so to promote spatial thinking throughout education. They have done so in a wide variety of settings, to students of all ages, in lecture rooms, computer laboratories, on mobile devices, and in the field. Yet for all of this variety, a remarkably small number of themes are common. In this paper and keynote presentation, those themes that have helped to create a small but growing international GIS education community are identified. These include a focus on problem-solving, inquiry-driven pedagogical techniques that use real-world data and geotechnologies to analyze spatial patterns on a local to global scale. They focus on classroom, community, and careers, and promote scholarship, citizenship, and artisanship.

Yet despite progress made since 1990, not only do challenges remain, but forces are acting that could confine spatial thinking in education to a relatively small part of educational practice and research through 2020. These forces include an overreliance upon standardized assessments, budgetary constraints that curtail necessary components such as fieldwork and IT support, a lack of a curricular fit or home for GI (Geographic Information), and an overemphasis on science and mathematics to the exclusion of other key disciplines critical to nurturing spatial analysis. This paper makes recommendations about what needs to happen to advance the use of GIS in education at all levels. This includes establishing a disciplinary home for GIS throughout education, an increased emphasis on portfolios and other authentic assessment instruments, and the funding and establishment of a center that promotes research in the implementation and effectiveness of GIS in education.

The future of GIS in education will also be impacted by citizen science initiatives, volunteered geographic information, the cloud computing environment, mobile computing, open data portals, and open application programming interfaces (APIs). Spatial analysis with GIS addresses the essential issues of the 21st Century. Natural and human-caused hazards, urban sprawl, sustainable agriculture, renewable energy, public safety, water quality and availability, biodiversity loss, healthy economies, and other key and complex issues of our time can be better understood through the spatial framework. Spatial thinking and analysis must take place throughout education, not only to have a positive impact on teaching and learning, but also on society as a whole, which would benefit people and the planet. If this does not occur, we will be on uncertain footing in education, and we will be on precarious ground as a global society. We will essentially be sleepwalking into the future.

Jekel, T, Koller, A., Donert, K. & Vogler, R. (Eds.) (2011): Learning with GI 2011.

1 The Case for Spatial Analysis Using GIS in Education

People have always been fascinated with investigating their home – the Earth. To understand our planet, ancient scholars in Rome, Greece, and China founded the study of geography over 2,500 years ago. Today, geography is more relevant than ever, as issues of climate change, economic globalization, urban sprawl, biodiversity loss, sustainable agriculture, water quality and quantity, crime, cultural diversity, energy, tourism, political instability, and natural hazards grow in importance on a global scale but also increasingly affect our everyday lives. To grapple with these issues requires a populace that has a firm foundation in geography, a populace that can see the "big picture" but also that understands how different patterns and trends are related from a global scale down to the local community. Geography is concerned with all of the relevant issues of our time, because all of these issues have a geographic component.

For centuries, maps have stirred imaginations and inspired explorations of the unknown. Today, maps are used to help understand relationships across areas and regions. These spatial relationships are analyzed using maps in digital form within a Geographic Information Systems (GIS) framework. In a GIS framework, rather than as static documents, these maps are dynamic. They can be grappled with and combined with other maps and data sets, as well as charts, databases, and multimedia. GIS, together with Remote Sensing and Global Positioning Systems (GPS), make up the geotechnologies, which help people make everyday decisions and plans more effectively and efficiently. With the complex issues confronting societies, paper maps simply won't do – their content, symbology, or scale cannot be changed and they cannot be analyzed quantitatively as a GIS allows on digital spatial data.

In education, GIS offers a powerful decision-making toolkit that can be used in educational administration, educational policy, and in instruction. GIS offers administrators a way to visualize and manage everything from monitoring campus safety, mapping campus buildings, cables, and other infrastructure, routing school buses, planning where and when to close schools and open new ones, and strategizing recruitment efforts. GIS provides educational policymakers with tools to see patterns in educational achievement and where to target new programs. In instruction, GIS in the hands of students helps them to understand content in a variety of disciplines, not only in geography, but in history, mathematics, language arts, environmental studies, chemistry, biology, civics, and many more. GIS is used as an inquiry-driven, problem-solving, standards-based set of tasks that incorporates fieldwork and provides career pathways that are increasingly in demand. It helps students think critically, use real data, and connects them to their own community. It does so in informal, primary, secondary, and university settings and appeals to today's visual learners. Geotechnologies, along with biotechnologies and nanotechnologies, are the three key skills and job markets identified by the United States Department of Labor for the 21st Century (GEWIN 2004). It therefore is taught in the context of promoting spatial thinking.

What is the relationship between birth rate and life expectancy? Why does this relationship exist? How will climate change affect global food production? How did the toxic spill in Hungary affect water quality and villages downstream (KERSKI 2010)? Students using GIS explore the relationships between people, climate, land use, vegetation, river systems, aquifers, landforms, soils, natural hazards, and much more. With the flood of information available to students today, they need to be able to deal with uncertainty about data, to understand its limitations with regards to error and omissions, and to effectively manage it. GIS is a tool that provides holistic computer and management skills for students, a part of a geospatial technology competency model recognized by the UNITED STATES DEPARTMENT OF LABOR (2010). The model not only includes computer competencies, but equally as important, personal and organizational competencies (DIBIASE et al. 2010).

Using GIS provides a way of exploring not only a body of content knowledge, but provides a way of thinking about the world (BEDNARZ 2004; KERSKI 2008). These skills were identified as essential to K-12 education by the United States NATIONAL ACADEMY OF SCIENCES (2006). The geographic perspective informs other disciplines. When epidemiologists study the spread of diseases, scientists study climate change, or businesspersons determine where to locate a new retail establishment, they use spatial analysis. In each case, GIS provides critical tools for studying these issues and for solving very real problems on a daily basis.

Spatial thinking in instruction also incorporates and depends upon fieldwork, which is critically needed for understanding and appreciating our world (SOBEL 1999; LOUV 2006). Students can gather locations with GPS and attribute information about tree species, historical buildings, water quality, and other variables on a field trip or even on their own school or university campus. GIS-based questions begin with the "whys of where" – why are cities, ecoregions, and earthquakes located where they are, and how are they affected by their proximity to nearby things and by invisible global interconnections and networks? After asking geographic questions, students acquire geographic resources and collect data. They analyze geographic data and discover relationships across time and space.

Geographic investigations are often value-laden and involve critical thinking skills. For example, students investigate the relationship between altitude, latitude, climate, and cotton production. After discovering <u>where</u> cotton is grown, and that much is grown in dry regions requiring irrigation, they can ask "<u>Should</u> cotton be grown in these areas? Is this the best use of water and other natural resources?" GIS helps students to act on their investigations, to put their recommendations in place, to improve the quality of lives of people and the health of the planet. Students present the results of their investigations using GIS and multimedia. Their investigations usually spark additional questions, and the resulting cycle is the essence of geographic inquiry (Fig. 1).

Our world is constantly changing. These changes include those brought about by physical forces such as erupting volcanoes, meandering rivers, and shifting plates, but also those brought about by human forces, such as urbanization and agriculture. Students use GIS to understand that the Earth is changing, think scientifically and analytically about why it is changing, and then dig deeper: <u>Should</u> the Earth be changing in these ways? Is there anything that I should be doing or could be doing about it? This captures the heart of spatial thinking, inquiry and problem-based learning. It empowers students as they become decision-makers to make a difference in this changing world of ours.

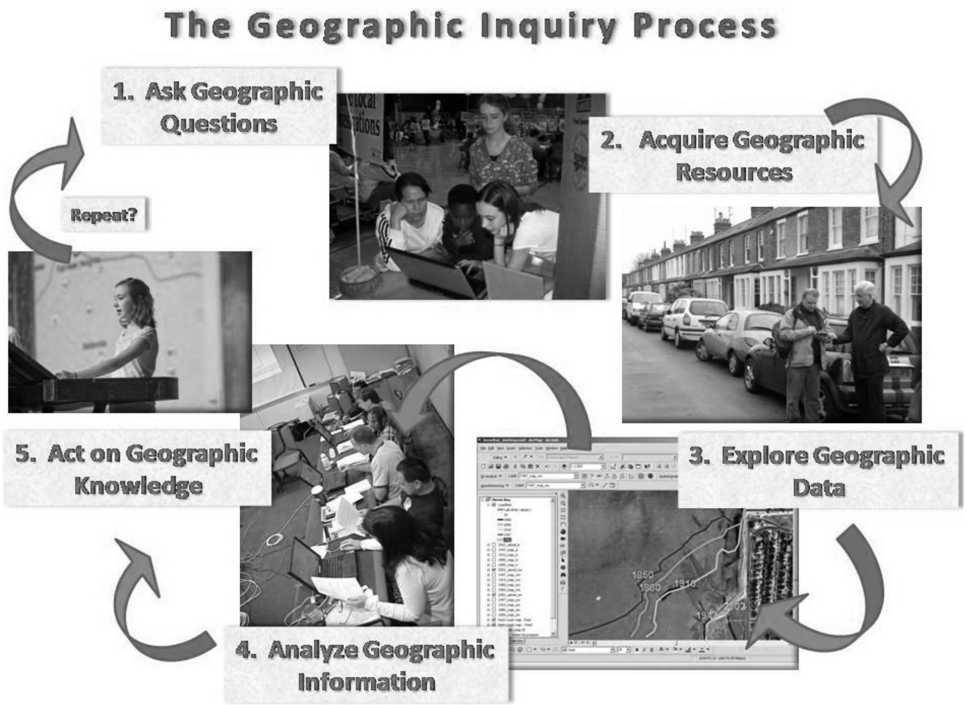

Fig. 1: The geographic inquiry process

2 Common Challenges and Benefits

Challenges and benefits in the landscape of GIS in secondary education have been the subject of many studies (KERSKI 2003, BAKER & BEDNARZ 2003). Challenges may be classified as technological and societal. Technological challenges include not only access to computers that have enough internal and graphics memory, hard disk space, and the proper software to be able to handle spatial analysis, but also access to those computers in the school and support from the school's information technology staff. It is tempting to relegate these challenges to the early days of GIS in education, but they remain challenges in many regions of the world today, even in many developed countries. Societal issues cast the greatest constraint on GIS becoming an embedded, required tool throughout education. These include the lack of awareness of spatial thinking and analysis and their importance in education and society. Coupled with the segmentation of education into discrete subjects, this translates into a lack of a "home" for GIS in the curriculum, and consequently a lack of funding and support for professional and curriculum development, and for research to examine the best methods of curricular implementation and assessment. In some countries, a lack of awareness exists at the educational policy level of what geography is and what it is not. Geography is frequently buried in the social studies and faces continued funding curtailments, particularly in the wake of renewed emphasis on Science Technology Engineering and Mathematics (STEM) in some countries. An over-reliance on standardized tests that do not assess critical thinking skills constrain use of inquiry-based methods such as GIS

(BAKER et al. 2009). Even at the university level, geography has not fared as well as other disciplines (DOBSON 2007).

Despite challenges, educators around the world, through formal and informal educational settings, and in primary, secondary, and university levels, find great value in using GIS and spatial analysis effectively in teaching and learning. An international examination of GIS use in secondary schools (MILSON et al., in press) features success stories in 33 countries of the transformational power of spatial analysis with GIS. These and other case studies and research projects show that GIS in education links students to their communities, to citizenship education, and to meaningful careers. It provides benefits in scholarship (developing skills in thinking and communicating), artisanship (gaining key skills), and citizenship (becoming thoughtful citizens) (KERSKI 2004). Students using geotechnologies exemplify the geographic inquiry process of asking geographic questions, gathering geographic data, assessing geographic information, analyzing geographic information, and acting on the decisions that they make with their new-found knowledge. Educators and students using these tools and methods are engaging in deep and meaningful inquiry, problem-based learning, peer mentoring, and working with real-world problems, tools, and data. They report enhanced student interest (CREWS 2008) and improved performance on some standardized tests (GOLDSTEIN 2010). They use geotechnologies as tools to grapple with relevant, current issues, rather than using technology for technology's sake.

The landscape of GIS in education is rapidly modified by trends and forces in technology, society, and educational policy. Technological trends having a positive impact on the use of GIS in education include increased internet bandwidth to move large spatial data files, faster and less expensive computers, and more powerful, easier-to-use geotechnologies. While energy shortages and consequential electrical outages could have a negative effect on GIS in education, longer-lasting batteries and solar-powered computers could reduce the potential negative effect. Still, concerns about the "digital divide" remain and GIS will be an option only for those with a decent internet connection and some sort of computer device, laptop or mobile. However, initiatives such as the worldwide "One Laptop Per Child," school programs that enable each student to have a computer, and bandwidth improvement initiatives occurring in many countries will ensure that at least the technological infrastructure is present in many more parts of the world (BARTOSCHEK 2011). In addition, one now only needs a smart phone to take GPS-tagged photographs and videos to build rich field-based GIS projects, rather than a separate GPS receiver and a digital camera. Voice-enabled GIS could be of particular help when the students' native language is not the same as that of the software, as well as for disabled or special needs students. Even more importantly, the rise of web-based GIS avoids software installation and local data storage while offering an easy-to-use interface. While web GIS does not offer all of the analytical capabilities at the present time that desktop GIS software offers, it could enable those educators and students move to the first level of spatial analysis (Fig. 2).

GIS in education benefits from an increased emphasis at the policy level that focuses on preparing students for the workforce. GeoMentor (http://www.geomentor.org) and local initiatives partner GIS professionals with educators. The trend toward open data will increase the number of schools and universities that can use that data and hence make it easier to teach with it. Distance education could increase the amount of GIS taught, the standardization of GIS curricula worldwide, and the number of students exposed to GIS. Even more importantly, the rise of geo-enabled devices and technologies, beginning with GPS receivers, and spreading to smart phones, web maps, and electronic sensors, enable volunteered geographic information and citizen science. This in turn has given rise to citizen demand for government transparency and accountability. As people use geographic information in their everyday lives, they more fully realize the value of geographic information, and may begin demanding educational reform that makes heavy use of inquiry and critical thinking such as GIS can provide.

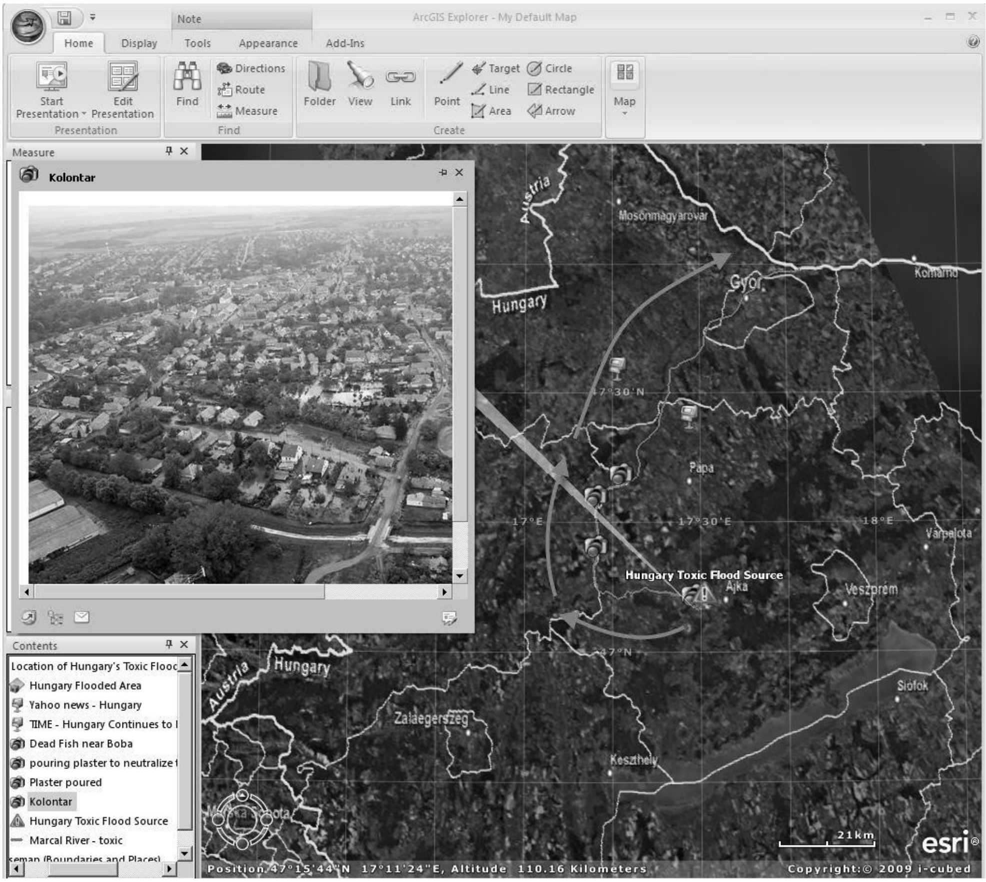

Fig. 2: Analyzing the October 2010 toxic spill in Hungary using ArcGIS Explorer

Another positive development that is only beginning to bear fruit is the recent call for the return of outdoor education (Figure 3). Yet funding shortfalls and high energy costs could curtail its potential. Increased demand for citizenship education, environmental education, and global education could hasten the growth of GIS in schools and universities.

Fig. 3: Educators and students using GPS receivers in the field at a professional development institute in Costa Rica

3 Sleepwalking or Moving Confidently Toward the Future?

What could advance the use of spatial thinking in education beyond the innovators and early adopters that ROGERS (1995) identified in his diffusion of innovations theory? Higher education needs to take an active role in promoting and supporting GIS in education at the secondary level. This partnership must include professional development, curriculum development (as exemplified by JOHANSSON 2008), and the use of secondary classrooms in research projects by university professors and graduate students. Partnerships between educational institutions with industry and nonprofit organizations are essential. Educational reform efforts that support inquiry-based methods throughout primary, secondary, and university institutions need to be promoted by those in education and by the general public.

In a similar manner in which Geographic Information Systems evolved into Geographic Information Sciences 20 years ago, GIS in education now has its own research base, developers, and educators who advance its theory and practice through research, curriculum, and teaching (KERSKI 2008). The research is anchored in geographic education but incorporates elements of experiential learning, problem-based learning, and some cognitive science. A GIS in education bibliography (on http://edcommunity.esri.com) reached 1,600 entries by 2011 with an increasing number of dissertations and other major studies produced annually. However, the GIS educational landscape remains small. Educational policymakers and administrators demand additional evidence that clearly shows how and why the use of any technology and method makes a difference in student learning. I recommend that an international GIS in education virtual research center be established to promote and support research that is desperately needed in this field. A five-year funded international GIS in education center would accomplish what the establishment of the National Center for Geographic Information Systems did in 1990 for GIScience – an established research base that develops and coordinates GIS-based curricular efforts, teacher training programs, and policy advocacy documents that are well grounded in learning theory. In Austria, a program exists where teachers are paid to conduct research (JEKEL, et al., in press). Could this model be a valuable component in such a GIS education research center?

Those who advocate the use of GIS in education tend to focus on its benefits for analyzing data and solving problems. While this has great value, GIS advocates must take steps to illustrate how GIS can help teach content to advance GIS at the educational policy level. PIAGET'S (1929) words that "the trouble with education…is that the best teaching methods are in fact the most difficult" are relevant here. Teaching with any inquiry-based method is more difficult because it is fraught with pedagogical uncertainties and inconsistencies in the data used and in the results that could be discovered. We need to instill the kind of educational culture where instructors are comfortable with this approach, and they are supported by their administrators for doing so.

As a community, we need to get past the perception of maps as mere reference documents and geography as memorization of facts. If GIS is "just" maps, then we are "just" using it to teach about climate, biodiversity, population, energy, water, and other key issues of our time. Rather than reducing possibilities, teaching with GIS enables students and educators, expands their horizons, and invites interdisciplinary education. In a decade where the amount of data will dwarf even the advances of the past decade, GIS will be absolutely essential for helping students sort through the plethora of information, helping them to think critically about data, but also about the issues that the data are describing. To advance GIS in education, we must get beyond promoting maps, which resonate with geography educators but with few other educators. We must not focus only on geography, which will likely remain constrained around the world given budgetary, educational policy, and curriculum pressures from other disciplines. We also must not focus simply on Science, Technology, Engineering, and Mathematics (STEM) education, which only resonates in some countries and varies depending on shifting educational policies and political slogans. Rather, we need to focus on something that nearly every educator, standard, and policy document state that they want to see more of – critical thinking. Positioning GIS in its rightful place as a critical thinking tool will advance it throughout secondary education and beyond.

A concentrated effort needs to be made toward preservice teachers. An increased emphasis must also be placed on portfolios and other authentic assessment instruments, for which GIS is especially suited (LINN et al. 2005). We must also point out that the teacher's role is critical to the geospatial learning process. Students may become more adept than the instructor at the technical tools, but it is the instructor who provides and frames the inquiry-based questions and issues. Hence, using GIS frees educators to do what they love to do best – engage students in meaningful issues. Teaching with GIS and even teaching about GIS is never just about the software; indeed, "button-pushing" is only a means to the end. Even the final map is only a means to the end. The end goal is the understanding brought about by spatially analyzing an issue, and the action it may lead the student to take to make a positive difference.

We must also promote the fact that GIS is an amazing unifier. Students and citizens worldwide bemoan the segmentation of education into discrete subjects and time periods, but GIS brings together content, skills, faculty, and students from different disciplines and levels. Spatial analysis, since it relies so much on visual learning, seems to be something that can effectively help students learn content and skills to become effective citizens and find meaningful employment. Most students want a career, not just a job, and one that makes a difference. Look around! It is plain that our 21st Century world is in dire need of those who can address the complex issues we face using the spatial perspective. As ORR (1994) better put it, "Now more than ever, we need people who think broadly and who understand systems, connections, patterns, and root causes…how to think in whole systems, how to find connections, how to ask big questions, and how to separate the trivial from the important. GIS is not simply a "nice to have" component of education, and it does much more than provide a meaningful a career path. It is essential for the future of our planet and its people.

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