A Model for Infusing GIS in the K-12 Curriculum

William M. Harris, Jr.
(Environmental Studies)

and

Richard E. Krustchinsky
(Education)

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(University of St. Thomas, Houston, TX)

Introduction

On December 26 2004, a British schoolgirl by the name of Tilly Smith saved her family and others at a hotel at Maikhao Beach in Phuket, southern Thailand because of what she had learned in a geography lesson at school[1]. She and her family were on their Christmas vacation when she recognized something from a class lesson occurring in the ocean and on the beach. The seas retreated quickly from the shoreline and she realized that a tsunami was coming. Screaming at her family and other tourists on the beach to run, they retreated to their hotel in time to save themselves from the fate of more than 200,000 people who died in that tragic event.

A 1988 Gallup poll commissioned by the National Geographic Society found that 1 in 7 people could not identify the United States on a world map[2]. In a 2003 paper by Christopher Shearer, the status of geographic education was summarized as follows:

> For a long time, geography suffered from uninspired instruction that was often restricted to memorizing place names, rivers, and capitals of countries and states. Often devoid of context or enthusiasm, geography eventually was lumped with history and civics into the social studies curriculum.[3]

In 1994, the U.S. Department of Education conducted a national assessment of geographic knowledge. They found that 70 percent of the students could be considered to have a "Basic" level of geographic knowledge, but only about 1 in 5 were "Proficient" and only 1 in 20 could be considered "Advanced" in their knowledge[4]. No Child Left Behind, the current national standards program for education, does not include geographic knowledge and threatens to drive geography further out of the educational picture.

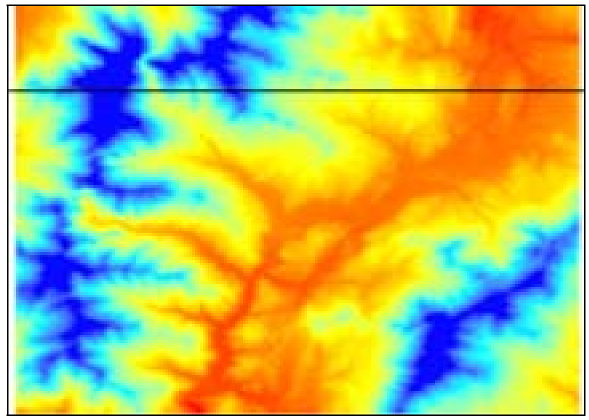
One way of improving the chances of including geographic content in the current education system is to make it integral to areas that are included in local, state, and national standards. Geographic Information Systems (GIS) software has the potential to be the linkage between geographic information and content knowledge from almost every discipline in the schools of the United States. GIS can integrate mathematics, geography, computer and analytical skills to show students that information occurs in the context of place.

Many people fail to see the relevance of geography to their area of educational expertise. Here are some examples of areas that have (but are not necessarily recognized as having) geographic reference (Fig. 1):

English	Stories occur in places. Although many people may have read the “Wife of Bath’s Tale”, how many know where Bath is?
Mathematics	Many mathematical applications have to do with the distribution of values across a field (surface). These distributions can be used to predict values at places between sample locations. Also, the modeling of these surfaces is an area of mathematical study in and of itself.
Science	Today, with the stress on Science Technology and Society (STS), scientific knowledge is becoming information in place. Information is being collected and analyzed by location, as well as by content.
Political Science	Although the most direct application of GIS to political science can be found in the practice of redistricting, the politics of a region is related to its culture. Culture is a result of the diverse history of its people, and is it also shaped by the underlying geography of place. Political boundaries are often controlled by geographic features that serve to protect, limit, or control growth.
History	The dissolution of the former Soviet Union has shown us that maps have been as much records of history, as they have been accurate representations of current events. As boundaries change, or names change (such as Burma to Myanmar), maps must also change.

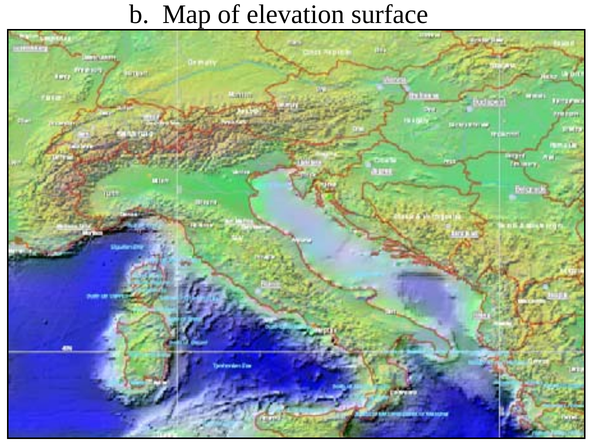
Foreign Language — Although many students try to learn a language as a collection of words to be linked together, language is as much a reflection of culture as words. If you look at the languages of a country, you will find regional dialects and meanings, which are often distributed based upon geography.

a. Map of British Isles showing location of Bath.

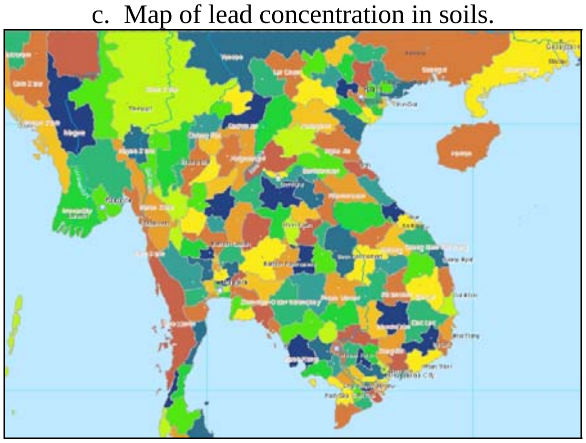


b. Map of elevation surface

c. Map of lead concentration in soils.



B. Map of southern Europe.



e. Map of southern Asia showing provinces.

f. Map of France showing regions.

Figure 1. Examples of using maps for teaching various disciplines (Data provided by ESRI).

Although none of these areas need to focus the bulk of their educational time to the use of GIS software, many of them can benefit from the use of the software in their instruction and completion of assignments by their students.

Spatial Thinking and K-12 Education

The Board on Earth Sciences and Resources of the National Academies (2006) focused on spatial thinking as a skill necessary for the modern world[5]. In their publication *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, the National Academies looked at spatial thinking as a valuable skill necessary for employment and success in the future, and at GIS specifically as a method for educators to teach spatial thinking skills.

In their report, they identified many difficulties in using GIS as a K-12 tool and pointed to the lack of software specifically designed (at that time) for educational use. Truthfully, the software available today remains principally "industrial strength", as stated in the publication. In their report they identified several items for consideration, including:

1. The capacity of GIS as a support system for spatial thinking;
2. The design of GIS as a support system for spatial thinking in the K-12 educational context;
3. The implementation of GIS as a support system for spatial thinking; and
4. Mechanisms for the redesign of GIS education software.

The publication concludes that there is great promise in using GIS to develop spatial thinking, but that the obstacles were probably too great (at that time) to be practical.

GIS in Education

Curriculum Considerations

There are many forces that shape a school's curriculum. Almost all of them are not only outside of the individual teacher's control, but they are usually dictated by the national, state or district requirements. This can take the true authority for the educational experience completely outside of the school environment. "Accountability" is the rule of the day, with students being tested like widgets and teachers being graded like machines that can only produce one kind of product in one way. Widgets/students that don't fit the model are often viewed as a failure of the teacher and the school, rather than a difference in the product.

In many school systems where accountability is "high stakes", teacher and student performance measures have been boiled down to perfunctory tests over subjects agreed to by committee, as if all educational achievement is measured by mathematics and Language Arts alone. We can see this focus culminate in tests after K-12 such as the Scholastic Aptitude Test and the Graduate Record Exam (General Examination). When reviewing standards from the 50 states, mathematics and Language Arts are the only things that are universally tested. In places where these courses are the only ones tested for, many times they are the only subjects stressed within the schools. If a school performs poorly on the pretest/practice tests, instruction in all other subjects (those not on the test) are dropped so that the students can be drilled for the test.

Getting your subject on "the test" is a daunting task. State Boards of Education must approve new areas to be tested, and performance standards must be set for each new subject. Once these standards are set and agreed upon (taking several years) one or more textbooks that coordinate with these standards must be accepted. From proposal to actual test, it may take five or more years before a new subject is added for testing. An additional question to ask before a new subject area is added to the testing is "what will be lost from the curriculum to include this new test subject?" Some schools have eliminated drama, art, music, social studies, geography, and other subjects that are not tested, in favor of more time in the subject areas covered by standardized tests.

To include GIS and spatial thinking skills and/or geography in a school's curriculum, you will either have to have it approved as a test area, or show how this tool can be used to teach content that is already included in the standardized tests. Most standardized tests do not test information in context but drill on rote memorization or replication of process skills in familiar situations (such as calculating an area of a circle that is slightly different in diameter than the one on the practice test). In this way, students learn to take the test, but do not learn how to apply the information and concepts to "real world" situations. Unfortunately, unlike the widget, our students have to live and operate in the real world.

State Standards

In Texas, the current standards are found in the Texas Essential Knowledge and Skills (TEKS)[6]. These standards can be found in grade specific requirements for kindergarten through fifth grade, and as subject specific requirements for kindergarten through high school. Although these standards are stipulations for the curriculum followed by every district in the state, every subject with a published set of standards does not necessarily have a proficiency test. In grades one through five, students are only tested in mathematics, reading, science and writing, yet not every subject at every grade level. For high school, the end of the year subject field tests are being created.

For each grade level, spatial thinking skills and the ability to use GIS would satisfy many of the knowledge and skills requirements (as seen in the broader sense of investigation, STS, and Piaget's "novel application" level of development)[7]. As an example, an applicable set of fifth grade TAKS standards[8] are:

ELEMENTARY SCIENCE—GRADE 5

Objective 1: The student will demonstrate an understanding of the nature of science.

Objective 1 is focused on the student as a scientist. This objective is found in grades 5, 8, 10, and exit level. The nature of science is at the heart of all sciences, K–16. The skills developed in Objective 1 progress in sophistication and complexity as the student matures and advances academically. In order to understand scientific processes, students must perform the activities of scientists, which include making observations, collecting data, and drawing conclusions. For instance, student expectation (5.2)(B) states that students are expected to "collect information by observing and measuring." Rather than just lecturing to students on how to use lab equipment, the teacher should give students the opportunity to work with thermometers, balances, measuring cups, and other lab equipment. Activities related to the TEKS of Objective 1 develop students' critical-thinking skills and problem solving abilities. Using critical-thinking skills to apply science concepts is the primary goal of science education. To best develop these skills, scientific processes should be taught and reinforced throughout the curriculum instead of as an isolated unit.

Objective 4: The student will demonstrate an understanding of the earth sciences.

A basic knowledge of the earth/space sciences allows students to understand how Earth's physical features are shaped by forces and are continually changing. These changes can affect the availability of resources, many of which are limited. The earth/space sciences lend themselves to the study of many types of systems, cycles, and change. Through the study of the physical features of Earth, the moon, and the sun, students begin to understand the universe as a dynamic system. Earth/space science concepts learned at the elementary grades and developed in sixth through eighth grades provide the connection for the earth/space science integrations found in Biology and IPC, which will be assessed at grades 8, 10, and exit level.

As found in objective 1, "*students must perform the activities of scientists, which include making observations, collecting data, and drawing conclusions*" does not call for rote memorization, but for an understanding of the use of science in context. In many cases, that context is place, or geography, yet is not tested as part of the standardized test.

National Standards

The National Science Education Standards (NSES) were established by the National Research Council in 1996 as a set of guidelines for primary and secondary education in the

United States. The intention was to “reform” science education in the United States by moving from traditional education to outcomes-based education. Examples of these standards are as follows[9]:

Earth and Space Science Standards

Levels K-4	Levels 5-8
Properties of earth materials Objects n the sky Changes in earth and sky	Structure of the earth system Earth’s history Earth in the solar system

Levels 9-12
Energy in the earth system
Geochemical cycles
Origin and evolution of the earth system
Origin and evolution of the universe

Science and Technology Standards

Levels K-4	Levels 5-8 and Levels 9-12
Abilities to distinguish between Natural objects and objects made by humans Abilities of technological design Understanding about science and technology	Abilities of technological design understanding about science technology

As with many of the “standards” that have been established, there are very few specific requirements and many “general area” requirements can be found within the NSES. Application of these national standards falls to state, local, and district curriculum professionals. Complicating the use of these standards is the No Child Left Behind legislation.

No Child Left Behind and the Problem of Standards

The No Child Left Behind Act of 2001[10] was passed to improve education in the United States. This was done not by increasing real funding to the schools or by funding curriculum development programs, but by establishing accountability standards by which states, school districts, and schools could be judged. Schools failing to meet these standards could be closed, or parents at these schools could move their children from “low performing” schools to other schools. Principals and teachers could be “reassigned” if their schools failed to perform at the “adequate” level of performance.

The potential of losing your job, or seeing your school “shuttered” is the “big stick” method of enforcing standards. Passed by a bipartisan congress and signed into effect by President Bush, the No Child Act Left Behind Act was to lift American school children’s skills and knowledge to a position, at the very least, equal to children in other countries. This is a position that had slipped over a period of about 30 years. Many companies were finding that American’s could not handle science- and/or technology-based jobs such as data entry and those jobs were being exported to other countries with higher education standards and proficiencies.

An unfortunate effect of the No Child Left Behind Act has often been a single-minded focus on the education system on those subjects tested under the national accountability standards. Geography and spatial skills are not among the tested standards under this Act. As many educators have found “if it isn’t in the test it isn’t in the classroom”, particularly in schools that have underperformed and are in danger of closing.

Obstacles to Implementing GIS

Teacher Preparedness

Teachers are required to take on many roles within the classroom. Educator, parent, confidant, arbitrator of disputes, policeman, and drug enforcement agent are among the roles of a teacher. In many districts, this also includes instructional technology specialist. Teachers must become at least somewhat proficient in operating and fixing overhead and slide projectors, television sets and DVD/VCR combinations, computers (many with LCD projectors), printers, and laboratory equipment.

Most teachers get into their first classroom with only one instructional technology course (at best) and a general knowledge of the use of the equipment and software that they are to use. When you include the paperwork of lesson plans, student evaluations, proficiency reports, and other expectations placed on teachers, there isn’t much room to “play around” with new software and methodologies that are available. In most cases, if the district doesn’t require something to be used in instruction, and doesn’t provide instruction on how to use the technology/software, a teacher simply doesn’t have time to do this himself or herself.

Most “out of the box” GIS packages are, as stated in *Learning to Think Spatially*, “industrial strength” applications, difficult for even trained individuals to use and keep up with or they are single-use applications that “mimic” GIS software functionality without the potential for wide spread use. ArcGIS, for example, isn’t the kind of program that you can learn easily how to *install* in an afternoon course for teacher’s on an in-service day, much less learn how to use the program and how to develop curriculum. For many of our GIS students in college, a moderate level of skill development can be accomplished in 45 hours of classroom and computer laboratory time.

So the question is, how do we work with in-service and pre-service educators to add this “tool” for instruction, while expecting them to continue to satisfy all of the other requirements of their jobs? We will address this shortly.

Cost: Software and Computer Instrumentation

Another consideration for the implementation of GIS use in schools and school districts is the need for higher-end computer systems to adequately operate most GIS software. Many computers, especially those found in primary education facilities are considered “legacy” computers with minimal specifications, older operating systems, and poor reliability. While many K-12 educators may never use some of the higher-end functionality of the software systems available, they are not given the option of installing a “lite” version of the software. Indeed, many classroom computers could probably handle a “core” version of the software, but will choke on the requirements for special analytical capacity.

Maintenance of most schools computers is done through a central Instructional Technology center, or by a small group of instructional technologists. Their job is made easier if every classroom and every computer is standardized, containing the same operating systems, software and data. Requests for additional software or capabilities means that a classroom, or entire school may have to be modified to a different platform from that of the other rooms or facilities and maintained as a separate entity.

As an example, the authors of this paper provided a school district in Houston, Texas with a plan to add GIS as an integral part of K-12 education throughout their district. Although some individuals with the district were interested in our “no cost” (at least to them) proposal, it was shot down by the instructional technologists who were concerned with the implication of modifying their computer schema to include this software and access to database materials. Indeed, the management tool provided by ESRI for their software can be somewhat counter intuitive for many instructional technologists unfamiliar with this type of authorization management. Finding the authorization setup for a program entirely outside of that program (within another) isn't a standard for software, even if it is for the industry itself.

Lack of Curricular Materials tied to Specific District's Requirements

Although there are an increasing number of curricular materials being developed for use with GIS software, many of these materials are not adaptable to a district's or state's book adoption to be used by their teachers. While they provide "good examples" of how to use the system to display and analyze information relative to the topic (such as looking a hurricane Katrina's storm track), they do not easily integrate themselves into the district's or school's curriculum.

A potential answer to this problem would be for each district/state to develop GIS curricular materials to go along with each textbook, or to require textbook publishers to provide exercises and datasets keyed to their textbooks. This, though, would drive up the cost of books, or take up the time of instructional technology/curriculum professional, time that would be taken away from doing their other work for the district. Another possible solution would be for the individual teachers to develop curricular materials after being trained in the use of GIS. Unfortunately, the amount of instruction necessary to bring an individual teacher up to a level of ability in the use of a system that would allow them to either modify existing data, or to develop their own data (with proper registration, data integrity standards and logical consistency), is beyond many teacher's reach. Also, this would assume that the teacher had the time to make new shapefiles and assign the attributes in proper word format for analysis.

Model for Integrating GIS

With all of the hurdles in the way of using GIS, particularly in subject areas such as English which are not considered particularly technical fields, why would anyone outside of the field of GIS professionals propose infusing GIS in the K-12 curriculum?

To begin with, modern primary and secondary education has become all about the tests, standards and accountability. Students are often viewed as "education-able units" not as people with differing abilities, skills, and learning styles. Because of this, some school districts with lower performing students (those whose learning style isn't "serviced" by the curriculum as developed) are not missed if they drop out. Students who drop out early enough in their school careers do not impact the later year's test scores. These former students **do** contribute to the undereducated workforce of the United States, though.

Developing alternative, context-based instruction using spatial thinking skills as the glue between disparate subject areas may help to reinvigorate education and still allow schools to teach the skills needed to pass testing requirements. Events occur in places, scientific measurements come from somewhere, natural disasters happen to people in the places where they live, and stories take place in locations where people live (and even mythical places have locations and geographic features that can be mapped). Most students in the United States grow up with computers and know the basic operation of computer programs. While teachers may not be willing to try new things, their students may be willing to give the software a chance.

Teacher Preparation

Although GIS software can be complicated to master, there is a difference between a user of geographic data and GIS software and a person who develops professional quality map data, modifies software, or imbeds GIS capabilities in to other programs (such as developing a "map creation wizard" for a word processing program).

It has been demonstrated that elementary school students can use GIS software with appropriate supervision, conducting basic functions available for spatial analysis. Unlike some of their teachers, young students are not "afraid" of technology that is unfamiliar to them and will work with a software program if they are able to master at least some of its functions within a short amount of time. Anything that takes too long to master, even at a very basic level, is considered "boring" and the student will move on to something else. What is necessary for the use of GIS software in an elementary school classroom is a teacher who is proficient enough in the program's operation for them to be able to bring their students quickly to some measure of success in making a useful map.

At the University of St. Thomas, we have required an introductory course in GIS for Earth and Earth/life pre-service education majors for the last six years. These students take the course along with students in other disciplines spread throughout the University (so this course isn't an education course, per se). In the class, students learn basic operation of ArcView in the production of maps and the manipulation of geographic data, as well as learning about the development and functioning of GIS programs. Although the success of education students in this course has been mixed, some of the best course portfolios have been prepared by the education majors. For their final project, students are required to produce a portfolio of 15 maps, based upon some theme and supporting their major subject. By agreement with the education school at the University, students in the education program who take this course use ArcView to prepare lesson plans and curricular materials, with some of those students electing to produce bilingual packets. In this way, these students move into the classroom already “armed” with the knowledge of how GIS software works.

The easiest place to address teacher knowledge and skills in spatial thinking and the use of GIS would be in pre-service programs. Although it probably wouldn’t be necessary to devote an entire semester and course to GIS software, education students could be introduced to this software package in an instructional technology course in a three- or four-week period of time. They could be taught the basic operations of GIS; adding themes to a view, modifying the symbology of the themes to illustrate spatial relationships between data values and location, and the preparation of maps for printing.

For in-service teachers, the task becomes more difficult because these teachers didn’t learn to use this tool, and the necessity of spatial thinking skills, before they went into the field. As teachers with a variety of years in the classroom, they have already developed a teaching style and methodology that works for them and their students. Or at least seems to work for them and their students as based upon the scores on standardized tests. Asking a teacher to partially or completely change their teaching styles and methods might seem to be as radical as asking an elementary reading teacher to teach a high school calculus II course, beginning next week. If nothing else, the cognitive dissonance produced within the teacher might be enough for them to consider another form of making a living.

Obviously, no one can expect in-service teachers to learn this software on their own, on their own time, and then expect them to develop curricular materials keyed to their state, district, or schools curricular requirements without some incentives to do so. Many schools require teacher work days at the beginning and end of the semester where teachers attend full-, or half-day courses. If a school is interested in using GIS within their classrooms, an in-service day (or a few days) at the beginning of the semester could be used to introduce the software to a small cadre of teachers, along with providing them “pre-made” lesson plans and data that support that school’s curriculum. As those teachers become more comfortable with the software, and if the students are judged to have higher levels of proficiency because of the use of the software, then the school could teach other teachers the use of GIS software until the whole school staff is involved in this technology.

Software and Computer Program

Although it may sound somewhat radical for someone who has taught GIS for 14 years to say, ArcView 9.2 isn’t the tool for a majority of our nations teachers. GIS software, as it is now available for many teachers, suffers from a “Goldilocks” problem of either being too complex to learn, teach with, and teach their students to use, or too simple to be useful for anything more than data display purposes. It is hard to find a software program that is “just right”. Not since ArcView 3.3 has there been a package available that tends to work in the way needed for education.

Admittedly, ESRI and the other producers of this software are not specifically in the business of producing education software, but they would benefit from a cleaner line of progression from software to be used in a transition through the primary school market into secondary schools, and eventually college and professional use. There is a quantum jump between the software packages available to display geographic data (with remedial “analysis” capabilities) and those programs that allow for customization and true data analysis.

With ArcView 3.3, students could have many maps contained within a single file (which operates like having several paper maps with a book or file folder). This operates well with students because materials are contained within one file and requires only the management of *that* file by the student. In the current version of the program, students with ten maps must keep track of 10 files, remembering where they are, what they are (difficult for any professional, and requiring a naming scheme to be developed for each map within a project), and tracking changes between maps requires students to open and close files over and over again, increasing the chance for a drive access error, or operator error in saving/changing file names between versions.

A software "progression path" needs to be developed, with customizable options within each individual software package, so that students can learn basic operation and graphical user interface (GUI) buttons that do not change in their functions between versions of the software. A logical progression in software options would **add** buttons with new functionality to compliment those already learned. Removing buttons, moving them around, placing them on customizable (if you know how to customize in the first place) bars, or moving them to "right-click" options is very confusing, even to those who are somewhat proficient in using GIS. Moving up to the next level of functionality in the "progression path" should not include having to learn a completely different version of the software or operational schema.

One might ask, "why would software companies develop these 'progression pathways' for their software when they are not specifically involved in the education market?" The answer is obvious, and already known to these companies. Students who use their software in K-12 education and beyond, begin to expect that their employers will have this software functionality when they are hired. Companies who have many employees with the skill to use GIS software, but who do not have this available as a workplace option, will either lose those employees to others companies, or will have to purchase the software to compete in the market place. If there aren't enough trained individuals entering the workforce knowing how to use GIS software (at least at a basic level), or even knowing about its existence, then companies will not be buying the software, support, and training for their employees.

As for the total cost of the hardware package needed to adequately operate GIS software packages, a "progression path" should allow elementary school students and teachers to achieve at least a "minimal" level of proficiency with their legacy computers. Americans and the congress seem singularly disinterested in funding education at the appropriate level to achieve the goals required by standards, and more than willing to "punish" those schools who fail to achieve, even if they lack the tools to do so. In many cases, schools should be able to contact the local businesses and granting agencies directly to ask for funds to equip their schools. It is in the best interest of businesses to have a well trained workforce, and they may have to pay directly (rather than indirectly through taxes) to get this workforce.

Curriculum Development and the Importance of Geographic Knowledge: A Model

Almost every professional group issues a list of items that a "knowledgeable" person needs to know. To be literate in the arts the experts will tell us how many paintings/painters that we need to be able to identify, operas that we should have watched, and musical styles that we should have listened to. To be knowledgeable in the sciences, we should all know the basic laws of nature, evolution, particle behaviors, chemical principles, and environmental concerns of today. What most of these organizations don't do is explain how the educational system is suppose to teach all of this (especially the parts not covered by the standardized test), how the curriculum is suppose to be developed to teach all of it, and (more importantly) why most people can be born-live-die in a fairly satisfactory manner without knowing *any* of it.

Indeed, many in academia today look with distain at the K-12 system as being inadequate and providing a “product” that has become less educated with each passing year. Many of these same academics are also not inclined to do anything to help the K-12 system become better, because it isn’t considered as academically rigorous as conducting research to produce a professional research paper and will not count as heavily towards tenure or advancement. Many of those academics in the Earth sciences who have been heavily involved in working with K-12 teachers and their students have reached retirement age and will not be replaced with a junior faculty member with similar responsibilities and/or expectations[11].

For teachers to efficiently use GIS and spatial reasoning skills in their courses, they must be trained (of course) **and** have appropriate curricular materials available to them. Who will provide the curriculum support for infusing GIS into the classroom then becomes the question. If most teachers are not able to produce these materials, most instructional technologists lack specific content knowledge to be able to produce the materials, and college/university professors are unwilling to take the time to produce them, then who will.

It is our view that this duty will fall on those very societies who call for the teaching of their subjects within the education system. Geographic societies will have to ask their membership (or will have to raise funds to pay people) to develop curricular materials that can be provided free off of the Internet, or at minimal price to in-service teachers. Historical societies will have to identify the appropriate maps to be used within the instruction of history classes, and then make those data layers available for teachers to use. Similarly, scientific societies need to produce map data layers that are readily usable by teachers within a wide range of expertise (K-12) in content knowledge, as well as lesson plans to support that data. These activities need to include things that teachers can do in their own building, campus, or nearby parks, ponds and/or hiking and biking trails. They need to be easily modifiable to include the school district's own math, science and social studies curriculum and state objectives.

Additionally, education professionals will need to develop instruction for teachers that will allow them to learn how to teach basic spatial reasoning skills and the use of GIS software. In this way, teachers entering the field will have the skills and abilities to use available materials, as well as develop a curriculum plan that infuses the use of GIS into their curriculum. In science, for example, by a certain point in a student's education they should be as comfortable about using GIS to print a map of their state as they are about using a ruler to measure a nail's length. Once the "tool" of GIS is used widely enough, students will wonder why a classroom computer doesn't have the software loaded on it, not how to use it to write a paper or conduct an investigation with it.

As an example of how geography, spatial reasoning, and GIS could be infused into the K-5 curriculum, we have been working with Helms Elementary School (Houston Independent School System) in Houston, Texas. This last spring, Helms held their "Super Science Saturday" event which was cosponsored by the professors and students from the University of St. Thomas. Faculty members from the education, chemistry, and environmental studies departments, as well as students from the American Chemical Society student chapter and education department participated. One of the purposes of Super Science Saturday is to bring the students and their parents to school to learn in a "stress free" environment where they can learn together about the importance of math and science, as well as have fun[12]. Local health professionals also talk with the parents about health issues important to the local community.

Helms is a minority-majority school with many parents whose first language is Spanish, and who may have a somewhat limited English capability. At Super Science Saturday, the parents are involved along with the students in conducting experiments, learning about science concepts and current research, and (almost more importantly) having fun while doing so. At this year's Super Science Saturday, the co-authors presented a lesson to students, their parents and teachers on geography, GIS and the use of Global Positioning Satellite technology.

Students were first familiarized with number lines, numbering systems and graphing. Students must learn relatively early in their educational experience about positive and negative numbers, as well as the number line. They also learn that graphs (XY) have two number lines, with negative y-values falling below the x-axis and negative x-axis numbers falling to the left of the y-axis. This is also how GIS handles latitude and longitude (Figs. 2 - 4) with western longitudes being negative and southern latitudes begin negative. Students were then shown a graph paper with positive and negative y-axis values ranging between +90 and -90, and x-axis values between +180 and -180.

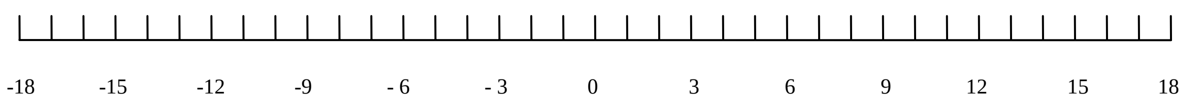


Figure 2. Graphing, using a number line, is a TEKS requirement for Grade 2.

Students were shown how to plot points on the graph, based upon x- and y-value pairs. They were then shown where on the Earth (more specifically the North American continent) those points were located. At that point they were given a brief instruction on latitude and longitude and the use of a GPS (Fig. 5 - 6). Students worked in groups of two or three, along with their parents, doing two investigations using the GPS devices. One was to determine the location of five orange flags that had been located within the playground area. The other was to

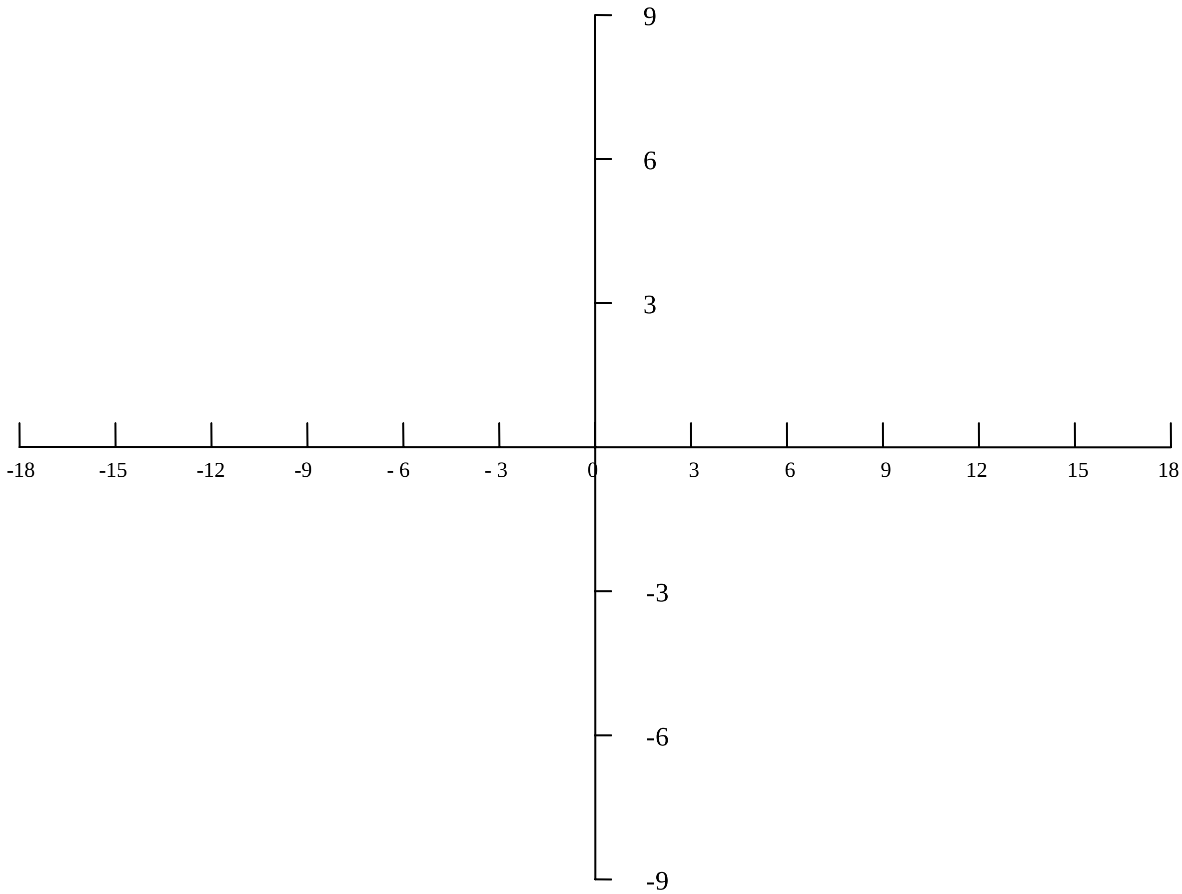


Figure 3. The number line, when used as X and Y coordinates, can be then used for graphing. Graphing is a third grade TEKS requirement.

identify the objects whose locations were provided to the students. This included objects such as benches, tables, the monkey bars, and a swing set (fig. 7 - 8).

They were then shown a geographic map of the continents with the graph overlain, and a map of Texas with longitude and latitude (Figs. 9 - 10). For all of these students and their parents, the concept of longitude and latitude were foreign before the exercise and we did not leave that Saturday afternoon feeling that we had achieved a breakthrough in teaching about GIS and GPS, or even about geography. But we had sparked interested in a few people who might be more interested in the future when those subjects come up in their courses. They will be able to

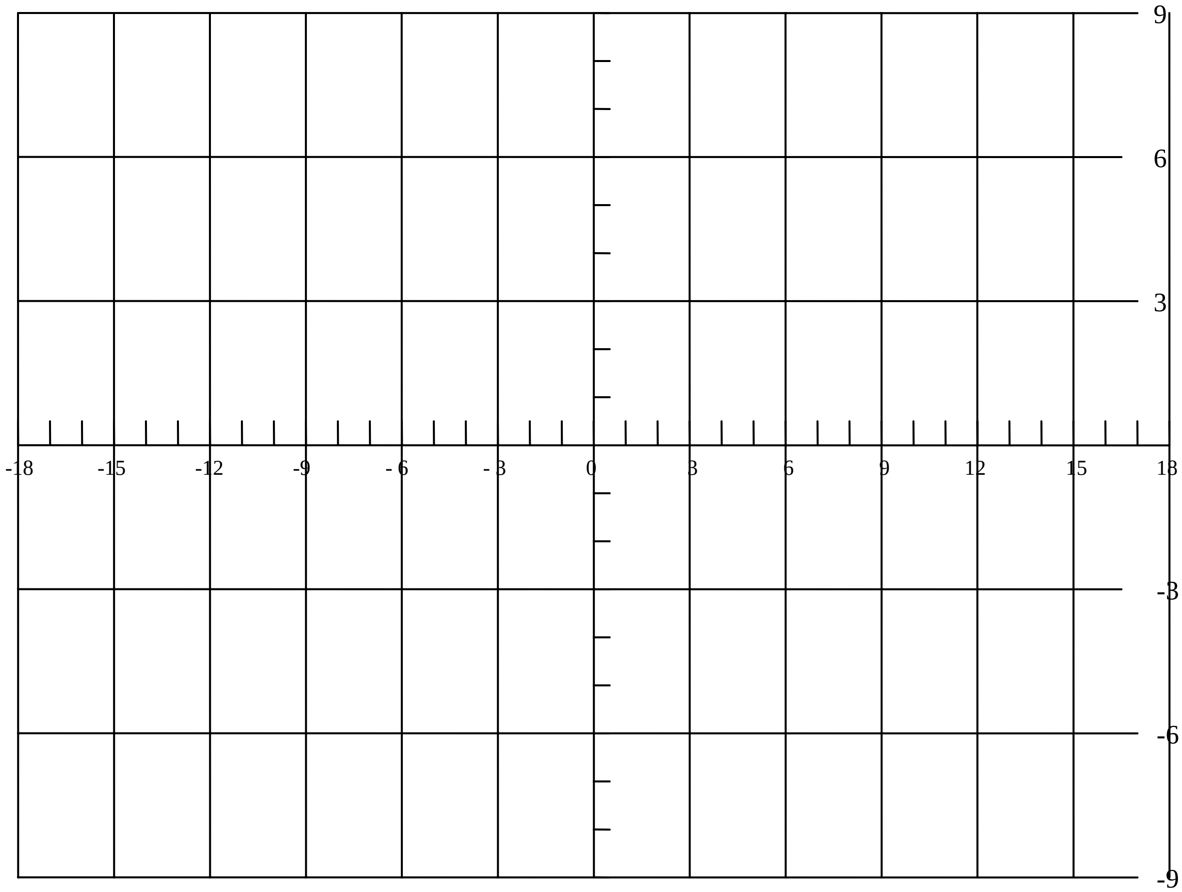


Figure 4. Using an XY graph, with negative 90 and positive 90 for the Y-axis and negative 180 and positive 180 for the X-axis, you now have latitude and longitude. The use of maps is also a requirement for third grade in the TEKS.

tell other students about their experience with the use of GPS devices, and an introduction to a computer program that was able to show them where their school was located (GIS) as introduced to them that day.

Two teachers watched for a while from a short distance from where the students were learning from us. Eventually they came over and were initially skeptical that this was something appropriate for K-5 education. The co-authors went through the lesson with those teachers, stopping to explain how learning about geography and latitude/longitude was simply a fancy way

Figure 5. Dr Harris Instructs students in the use of graphing, longitude and latitude and in mapping.

Figure 6. Drs. Harris and Krustchinsky point out how to use a GPS device.

Figure 7. Dr. Harris instructs students how to use the GPS device.

Figure 8. Students use the GPS device to find the location of five flags on the playground.

of learning about graphing, which is a skill tested upon in the standardized test. We showed them how they could use the tiles on the floor of their room as graphing blocks and how they could put things on the floor, and have their students determine the location of those object simply by counting the number of blocks from some reference point. From the data the students

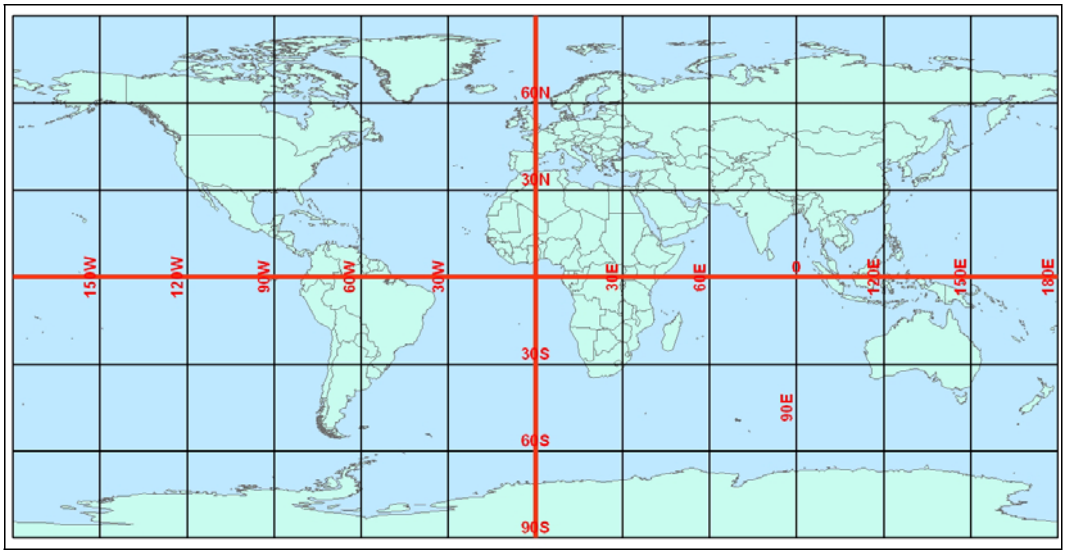


Figure 9. Overlay of latitude and longitude upon the distribution of continents.

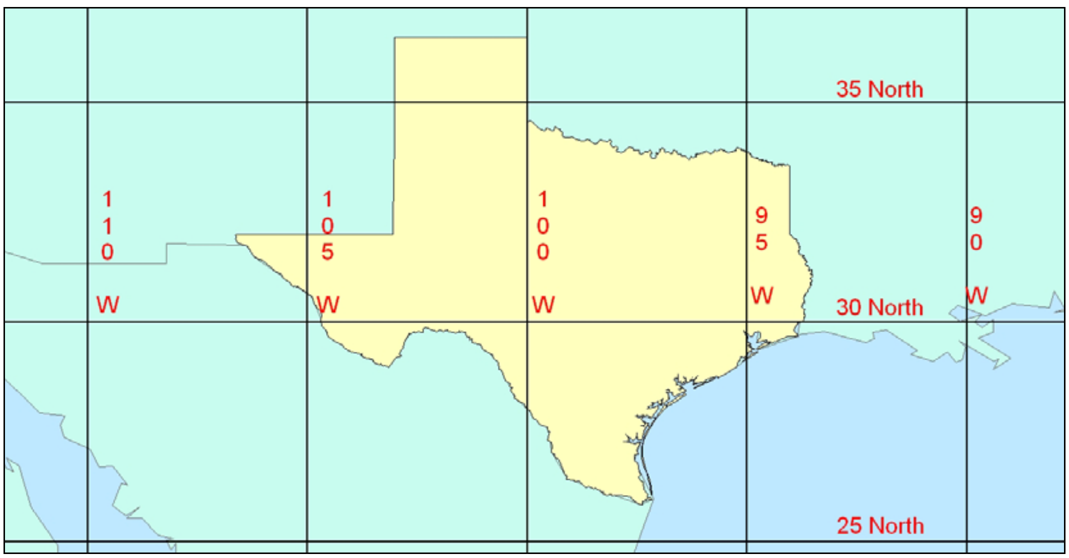


Figure 10. Unprojected latitude and longitude map for Texas.

collected (literally off of the floor of their classrooms) they could then construct graphs showing those values, and then learn how this is also how we locate objects on a map.

The next step with Helms will be to work with their teachers to show them how to teach graphing as both a mathematical tool and a geographic tool. By starting with simple relationships of place and value, students then can learn about the equator as an example of an x-axis. The teachers can introduce maps in the early years (perhaps K-3) as an instructional tool.

By the fourth grade, students should have enough general geographic knowledge to prepare their own maps, using a simplified mapping program and "canned" spatial data.

Super Science Saturday, math, science and/or social studies nights with families, after school programs, summer school enrichment programs and after school math and science clubs could also be places where GIS can be introduced to students. These informal educational methods can be readily implemented in almost any school situation K-12. Curriculum development, on the other hand, and the acceptance of spatial reasoning skills and adoption of the use of GIS in the classroom may otherwise take as much as a decade.

A logical progression of the use of GIS software in the educational system would be for teachers to "model" the use of GIS in elementary schools as an instructional tool in a diverse range of subject areas. If a history course or current events discussion includes information on Myanmar, the teacher should be able to bring up a map of that region and customize it to focus on the region affected by that event (historical or current). If a story in English includes a discussion of activities in World War II, a teacher should be able to produce a quick map of Europe, showing changes in territories held by axis and allied forces throughout the war. In science, teachers could discuss the spread of a disease, such as West Nile Virus, or Dengue Fever and include a map of the progression of these diseases northward into the United States.

In middle school, students would then potentially be familiar enough with the software to produce their own simple maps that they could then use in short presentations, reports, or investigations. Having a somewhat more "robust" version of GIS software in middle school, the students could go beyond simple map display, to represent information using simple symbology (such as a point's size to represent population, or by using a star to represent a capital). Finally, in high school, students would ideally be producing several maps per week as part of reports for a variety of classes. This could include using GIS to produce a map of the distribution of French dialects in France for a French course. Ideally, an entire course in GIS would then be available for those high school students interested in learning about the use of GIS as a possible profession. Districts could also conduct GIS Fairs (similar to science fairs) to showcase the talents of their students to parents, and potential employers.

Some day, the ability to use GIS software will become as necessary as knowing how to use word processing, database, and spreadsheets. Information comes from places, and an ability to place that information in the context of place (spatial reasoning skills), is that makes the information "real."

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