SATELLITES: Students and Teachers Exploring Local Landscapes to Interpret the Earth from Space

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ABSTRACT

SATELLITES program is designed to introduce in-service teachers and K-12 students to basic geographic concepts, geospatial technology (e.g., remote sensing, GIS, GPS, and digital elevation modeling), related data, and applications in complex concepts in Earth System Science. Teachers, who received extensive SATELLITES training in a one-week summer institute in 2006, integrated concepts and technologies in their school curriculum the following fall by engaging students in inquiry-based research projects during an intensive field campaign. 151 K-12 teachers from 110 schools have received SATELLITES training over the last three years and over 10,000 students representing more than 300 schools from every state in the United States and several other countries including Canada, Australia, Great Britain and China have participated in data collection during field campaigns. In 2006, 1200 student observations were recorded and 600 students attended the 2006 annual conference where 60 inquiry-based research project posters were presented. After participation in SATELLITES, teachers' content knowledge in geotechnologies and related sciences increased significantly. Teacher's reported an increase in perceptions of their ability to do inquiry science and employ inquiry-based instruction. They also reported a significant increase in student engagement when students collected data and worked through the scientific process while participating in SATELLITES inquiry projects.

INTRODUCTION

As outlined in Getis et al. (2006), an introductory text for College students, geography has four main traditions: 1. Earth Science; 2. Culture-Environment; 3. Location; and 4. Area Analysis. These four are bound together by a 5th tradition, the geographic method (now referred to as "geospatial technologies"). "The term *Geospatial Technology* refers to the visualization, measurement, and analysis of features or phenomena that occur on the Earth including its landforms, climate, environment and infrastructure. It is therefore a powerful tool to study content areas like Geography, Earth Science, and Ecology" (Munro-Stasiuk et al., 2006). Geospatial technology includes Geographic Information Science or System (GIS), remote sensing and Global Positioning Systems (GPS). Munro-Stasiuk et al. define *remote sensing* as "the collection of information about an object without being in direct contact with that object." Environmental Systems Research Institute (ESRI, n.d.), a leader in the development of GIS software describes GIS as the integration of hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GPS is "a system of radio-emitting and -receiving satellites used for determining positions on the earth (ESRI, n.d.). While maps are prominent features throughout introductory geography textbooks, the same texts dedicate only a handful of several hundred pages to discussions of geospatial technology, geospatial data and applications (e.g. Bergman and Renwick, 2005; Getis et al., 2006). While these texts are excellent in terms of presenting introductory geographic content, the tools and data that are now so integral to the discipline are rarely introduced to students until much later in their undergraduate careers.

Considering the late introduction to geospatial technology in higher education, it comes as no surprise that geospatial technologies have not been widely introduced in K-12 classrooms in the USA. GIS has received much attention but even it has been not been adopted by large numbers of educators (Kerski, 2003; Berdnarz, 2004). Even though the national standards encourage the use of maps and other "geographic data" there is only one national geography standard that addresses geospatial technology and data directly (The World in Spatial Terms: Standard 1 - How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information) (National Geography Standards Geography Education Standards Project, 1994). This was noted by Gatrell (2004) who suggested training pre-service teachers around a core set of technology standards to cover geographic principles rather than covering geography standards directly. This strategy has the potential to broaden the impact of geospatial science beyond just geography courses. Kerski (2003) reported that science teachers outnumber Geography teachers 2 to 1 for use of GIS in the classroom and that chemistry teachers were the most extensive users because of water quality studies. Teachers have many reasons for reluctance to adopt new technologies such as GIS in the classroom including hardware and software requirements, time required to learn new software, time issues related to implementing a GIS classroom project, little institutional support, and teacher conceptualizations of geography (Berdnarz, 2004). Equally important, Berdnarz found that professional development in pedagogy (curriculum, instruction, and assessment) related to teaching with GIS has been given little attention at either the pre or post secondary level and that more time and effort should be spent in preparing educators to use geospatial technologies like GIS and developing appropriate curriculum for classroom use.

The SATELLITES [Students and Teachers Exploring Local Landscapes to Interpret the Earth from Space] program was established to provide educators with much needed professional development in geospatial technologies (see SATELLITES website at http://remotesensing.utoledo.edu/edu/SATEL.html). The program, offered to in-service middle and secondary grade-level educators, is aligned with and integrated into the earth science and culture/environment traditions within geography. SATELLITES is open to teachers who teach a wide range of classes including Earth Science, Environmental Science, Biology, and Physics, however, teachers who teach special education, Mathematics, Technology and Social Studies have also participated. Advertising is conducted through email, presentations at teacher professional conferences such as Science Education Council of Ohio (SECO) and by word of mouth. By including geospatial technology as part of existing school content, SATELLITES' approach is similar to Gatrell's (2004) training where he sought to integrate geospatial technologies in pre-service teacher social studies and Earth & Space science programs. By integrating geospatial technology into the existing curriculum, the emphasis is not on *learning* technologies, per se, but on teaching *with* technology. Curriculum standards can be supported in unique and exciting ways through the use of geospatial technologies. The primary goal of SATELLITES is to foster an understanding of the Earth and its environment, and how man and nature affect that environment through addressing Earth and Space Science and Geography curriculum. The program also addresses Physical Science, Science and Technology, Mathematics, Scientific Inquiry and History since geospatial technology can be effectively integrated into these subjects as well. Integration of subjects is both a reflection of the diversity of modern geospatial studies as well as the interdisciplinary nature of geography.

SATELLITES professional development focuses strongly on improving teachers' use of inquiry-based instructional methods. It is widely recognized that it is not sufficient to be simply an expert in a given field or in generic pedagogical strategies. Rather, true teaching expertise is found in the integration of the two to create a strong pedagogical content knowledge in which teachers have a strong grasp of a particular discipline and the skills needed to help students develop understanding of the same (Bransford et al., 2000). Furthermore, the single most important influence on student learning comes from teachers yet the most frequent instructional method employed in classrooms reported in a 2001 national survey was direct instruction (McEwin et al., 2003). These teachers also reported that fewer hours in the school day are devoted to science instruction than to instruction in Language arts or mathematics. Because of the nature of inquiry based approaches, when teachers apply these to their instruction of geospatial literacy, student motivation and interest in learning science, especially geospatial sciences may increase. Research tells us that inquiry based learning promotes students' motivation, fosters personal and situational interest, and connects curricula to issues that interest students or affects them directly (Blumenfeld et al., 1991), especially in minority urban students (Patrick et al., 2000).

It is critical that K-12 teachers and students are exposed to several academic areas including (but not limited to) geography since geospatial technology has been heralded by the United States Department of Labor as one of the top three emerging and evolving job fields in the US today with enormous job potential (Gewin, 2004). There are estimated 140,000 organizations worldwide utilizing geospatial technologies (Gewin, 2004) and some notable government agencies are promoting an active need for new and replacement workers. For instance, NASA indicates that it will need to replace 26% of its geospatial personnel within the next decade, while the National Geospatial Intelligence Agency (formerly known as the National Imagery and Mapping Agency) is expected to need another 7000 employees with GIS skills within the next three years (Gewin, 2004). Employment fields including homeland security (US DOL, 2005), environmental, civil government, and transportation (Gewin, 2004) are among the 'hot' areas for geospatial jobs in the current market.

The geospatial job market was estimated at $5 billion in 2002 (US DOL, 2005) and projected to grow to $30 billion in revenues by 2005 (Gewin, 2004; US DOL, 2004; US DOL, 2005) with a growth rate of 10 to 13% per year (US DOL, 2004). The Geospatial field has seen an increased demand for jobs (Careervoyages, 2005) and a definite need for individuals trained in these types of technologies. A lack of a currently trained and educated workforce is likely the reason that 87% of respondents of a survey of geospatial product and service providers had difficulty filling positions in this market (US DOL, 2004). Thus, education of geospatial technologies, especially at the early middle and high school levels, is becoming increasingly important in today's job market and economy.

PROGRAM DESCRIPTION

Overview - SATELLITES is a comprehensive professional development program for middle and high school teachers comprised of the following activities: 1) a summer institute, 2) web-based broadcasts to participating classrooms, 3) classroom visits by scientists (Faculty and Graduate Students), 4) a year-long, inquiry-based project, and 5) an annual conference held at the Great Lakes Science Center in Cleveland, Ohio. The program, which has been providing teachers with workshops since 1999 is a collaboration between University of Toledo, the OhioView Remote Sensing Consortium, and Cleveland Municipal School District (CMSD).

TOPIC	OVERVIEW OF CONTENT	DATA USED
Remote Sensing	What is remote sensing? The electromagnetic spectrum Types of satellites (geostationary/low earth orbit) Multispectral remote sensing Pixels and spatial resolution Remote sensing applications	Landsat TM and ETM+ Modis Google Earth true color satellite imagery (e.g. Landsat, QuickBird) TerraServer aerial photographs
GIS	What is GIS? 3-D GIS GIS applications	Google Earth imagery and layers Google SketchUp 3-D models
GPS	What is GPS? The GPS constellation Coordinate Systems Differential GPS Trilateration	Collected GPS coordinates
DEMs	What are DEMs Color theory and 3-D viewing (spectroscopy)	National Elevation Dataset (NED) 7.5 minute USGS DEM (same data as NED)

Table 1. Main geospatial topics covered in the SATELLITES program including content and data.

Figure 1. Photographs SATELLITES Activities during summer institute. A. Learning to using GPS and read geographic grids by viewing the GPS unit and walking as the coordinates change; B. Breaking the sky into quadrants prior to determining cloud cover and type; C. Heating things up activity indoors; D. Learning to use the IRTs; E. presenting results of the inquiry-based project.

SATELLITES summer institute (Figure 1) is hosted by scientists who have specialties in the fields of urban planning, geomorphology, climatology, and meteorology. During the institute, teachers learn concepts in climate and weather (e.g. clouds, GLOBE surface temperatures, energy budget, and atmosphere) and landforms and topography (e.g., glacial). Integrated into the institute's activities are a variety of geospatial technologies including remote sensing, geographic information systems (GIS), global positioning systems (GPS), Google Earth, Google SketchUp, Terraserver, OhioView data server, and digital elevation modeling. Table 1 summarizes the content covered for each topic and lists the geospatial data accessed and/or manipulated. Teachers agree to integrate these concepts and technologies in their classrooms during the following school year.

Using the concepts learned in SATELLITES, teachers are trained to work with their students to formulate a research question, collect and analyze data, and finalize the inquiry-based project over the course of a single academic year. To ensure implementation in the classroom, three semester hours of graduate credit is offered to participating teachers and is issued upon completion of the teacher/student inquiry-based project. Throughout the year, students are provided connections with real scientists and receive guidance on inquiry projects through videoconferencing, webcasts and classroom visits (Czajkowski et al. 2002).

An intensive field campaign engaged middle and high school students in inquiry-based classroom projects where they collected data using geospatial technologies and analyzed and reported their findings through a scientific process. In 2006, a total of 3090 students participated in the field campaign. This included students of teachers who participated in the 2006 summer institute and those who had attended the summer institute in previous years. Of these, 1495 (48%) were located in school districts designated as high need, Ethnicity of students included 1853 Whites, 592 Blacks, 455 Hispanics, 62 Asian, 4 Native American, and 69 other. 1640 students were from urban schools, 838 from suburban schools, and 450 from rural schools. 305 students had limited English proficiency, 146 were disabled, 69 were migrant, 1168 were economically

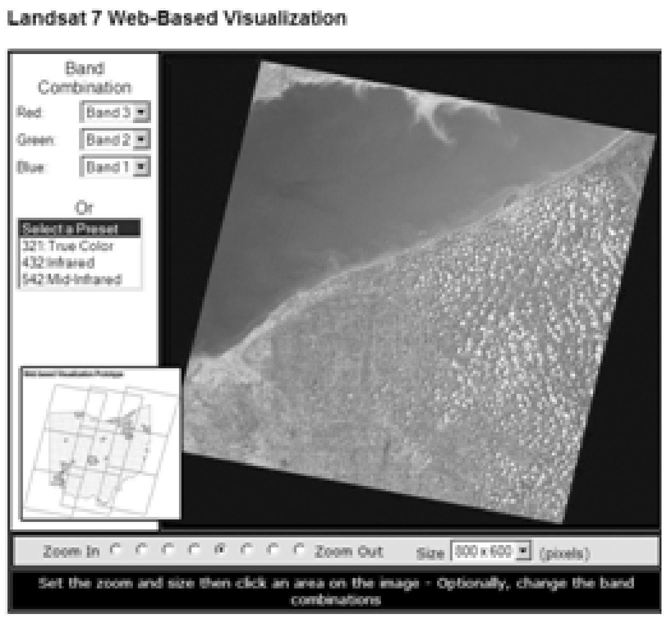

Figure 2. Screen captures of the OhioView Landsat web-based visualization. The inset satellite image is of NE Ohio and is displayed as a true color image. This image shows the relationship between Lake Erie and the adjacent land.

disadvantaged, and 245 were gifted. During an annual conference, student inquiry-based projects were showcased with the highest-rated projects receiving awards. The conference provides a local venue for students and teachers to network with scientists and to learn more about geospatial technology and related career opportunities.

As previously mentioned, the main goal of SATELLITES is to introduce basic introductory geographic concepts as well as more complex concepts in Earth System Science and physical geography through the use of geospatial technology and analysis of related data. The specific program objectives are to:

1. Improve teacher understanding of geospatial technologies and Earth System Science,
2. Engage middle and high school level students in real science,
3. Improve student understanding of geospatial technologies and Earth System Science through exciting, hands-on projects and opportunities,
4. Improve K-12 student familiarity with their local environment through collection and interpretation of scientific data with the help of university scientists and students, and
5. Promote access to free (or low cost) software and data.

Over 100 schools worldwide have participated in the surface temperature field campaign each year. Over 500 students and their teachers attended the 2007 SATELLITES Conference at the Great Lakes Science Center and over 50 inquiry-based research posters were presented and judged.

Geospatial Technologies - *Remote Sensing:* Teachers are introduced to remote sensing via a simple, mostly web-based activity that familiarizes them with true color and false color satellite images and aerial photographs. Aerial photographs and satellite images were acquired through Google Earth© and Landsat satellite images were acquired and analyzed via a data viewer on the OhioView website (OhioView Consortium, n.d.) (Figure 2). Teachers cut images of their school from the viewers and paste them into a PowerPoint poster template. This template is printed as a poster and used as a resource for teaching students the principles of remote sensing and about the local environment around each school. This initial exercise introduces the educators to some of the basic principals of image interpretation in remotely-sensed imagery through shape, size, texture, and association. Via image viewers, teachers learn about the resolution of Landsat imagery and how powerful these images are for visualizing the earth.

Basic principles of remote sensing including methods of image interpretation, the electromagnetic spectrum and spectral properties of Earth materials, satellite types, specific satellites (e.g. Landsat and Modis) and their applications, and orbit patterns are introduced to teachers. Teachers also learn to perform a simple unsupervised classification of Landsat data and see differences in landcover between two time periods using the free software, *MultiSpec*© (Purdue Research Foundation, n.d.). All teachers are given a CD that includes this software and small Landsat datasets that cover their own schools. During the remainder of the institute, teachers learn about climate principles including differential heating of Earth's materials, the energy budget, topography and land cover change, all of which are illustrated with multispectral satellite imagery.

Global Positioning Systems (GPS): Understanding how to use GPS is crucial for ground checking satellite data and for establishing and relocating sites of data collection in the SATELLITES program. Many lesson plans have been designed to incorporate GPS into courses and school curriculum (e.g., Davis School District, 2005; Herrstrom, 2000; Trimpe, 1999; Utah Education Network, n.d.). In this program, GPS is taught using an innovative approach of GPS treasure hunts based on the popular hobby of geocaching. Munro-Stasiuk (2006) described the approach and success of the GPS treasure hunt via teacher workshops, undergraduate general geography courses, and upper division undergraduate and graduate remote sensing classes. She noted that it is crucial for all individuals who work with geospatial datasets to understand how to use GPS units quickly and efficiently in order to guide themselves across a geographic grid and locate objects or pixels for the purpose of ground checking or setting up or relocating study sites. The GPS units used are Garmin eTrex WAAS (Wide Area Augmentation System) enabled units which can be bought over the shelf at any outdoors or sports store for a little over $100.

The treasure hunts are simple, easy to set up, and fun. Basically, objects are placed in the landscape either by teams of teachers or before the activity by the SATELLITES team. Teachers determine coordinates for each location and another group of teachers finds the placed objects with the coordinates provided. The activity is considered successful if all placed objects are found. Munro-Stasiuk (2006) reported immense success with retention of GPS concepts including understanding the GPS constellation of satellites, how GPS units detect satellite signals and convert those signals to coordinates

Figure 3. Screen capture of the Ohio Aerospace Institute in Google Earth©.

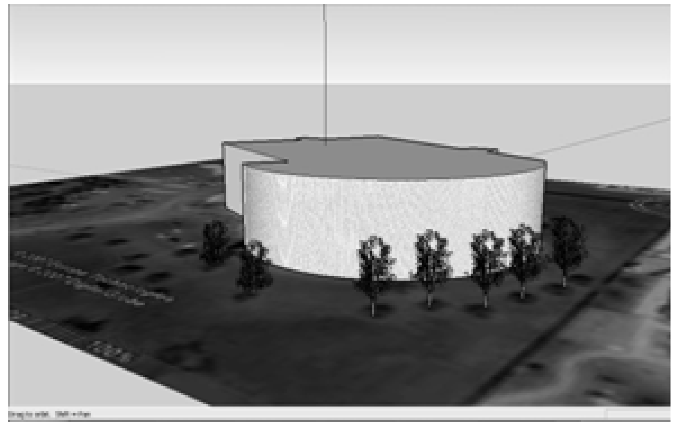

Figure 4. An initial basic simplified Google SketchUp© model of OAI.

***Figure 5.* Beeghly Center on the Youngstown State University campus, created in SketchUp© and displayed in Google Earth©.**

(trilateration), how to use the handheld instruments, and how geographic grids and coordinates are determined, used, and measured.

Geographic Information Systems (GIS): Instruction in GIS provides another foundation of the SATELLITES program as it provides an additional layer to "thinking spatially" and working with spatial data. A barrier to learning introductory GIS skills is the availability of free or low cost software. Importantly, in order for teachers to bring their GIS knowledge to their classrooms they need to have access to software that can be obtained for little to no cost, which unfortunately removes many commercially successful (yet expensive) software packages from use in the program. The virtual globe software, *Google Earth*© (GE) and its companion, *Google SketchUp*© (GSU) provides teachers with GIS fundamentals. Both programs are freely available for download via the web and encouraged for use in education by Google. The popularity of GE has allowed for widespread use of the software and thus, many teachers attend the Institutes with experience in its basic functionality (i.e. searching, zooming, tilting, panning, etc). Kluge (2006) provides a free comprehensive GE manual downloadable on the Internet to show teachers how this free resource can be integrated in the classroom.

One of the first tasks in orienting teachers to think spatially is to gather and plot in GE the GPS coordinates of the facility where the Institute is being held (such as the Ohio Aerospace Institute in Cleveland, OH) (Figure 3). Latitude and longitude coordinates can be entered directly as searchable items in GE and the software will automatically zoom to a 'ground level' view of the area. This provides a direct connection between the spatial data teachers manually gather and how the data relates to a larger spatial context. To promote GIS concepts, GE is used to search for addresses and set corresponding placemarks. Teachers utilize a geocoding procedure, which then leads to a discussion of the transition of their non-spatial data (the string of letters and numbers which constitutes the address) into spatial data (the GE placemark, which can then be referenced according to its coordinates). The GE "directions" feature allows the teachers to plot a pair of addresses and then have GE calculate the 'shortest route' between the points, similar to familiar web-based tools such as Google Maps© or MapQuest©. GE then allows the teachers to 'play' the route in which GE tracks the shortest path using a birds-eye view of the path. This also allows teachers to connect locations on a map to the spatial network distance between the items, leading to a discussion of some GIS network routing basics.

The 3D visualization tools in GE are also used to further explain spatial concepts. GE allows the user to examine landscapes with the imagery draped over the terrain, providing a pseudo-3D effect. For instance, GE's terrain provides global coverage, but terrain areas with vivid relief such as Mount Everest or the Grand Canyon can be viewed in perspective, in which areas can greatly approximate depth and height. These concepts provide a bridge for discussing the links among remotely sensed imagery, digital elevation models (DEM), and GIS. GE also contains 3D models of buildings in some major urban areas such as New York and Cleveland extruded to an approximate height.

The use of *Google SketchUp*© (GSU) extends the concept of 3D visualization even further. A user can take a 'snapshot' of the area being viewed in GE and import both the image and its terrain into the GSU environment. Then, 3D structures can be designed and built using the GE imagery and terrain as its base (Figure 4). Highly detailed buildings and additional objects can be exported at their correct spatial location in GE creating an interactive 3D environment (Figure 5). For example, a

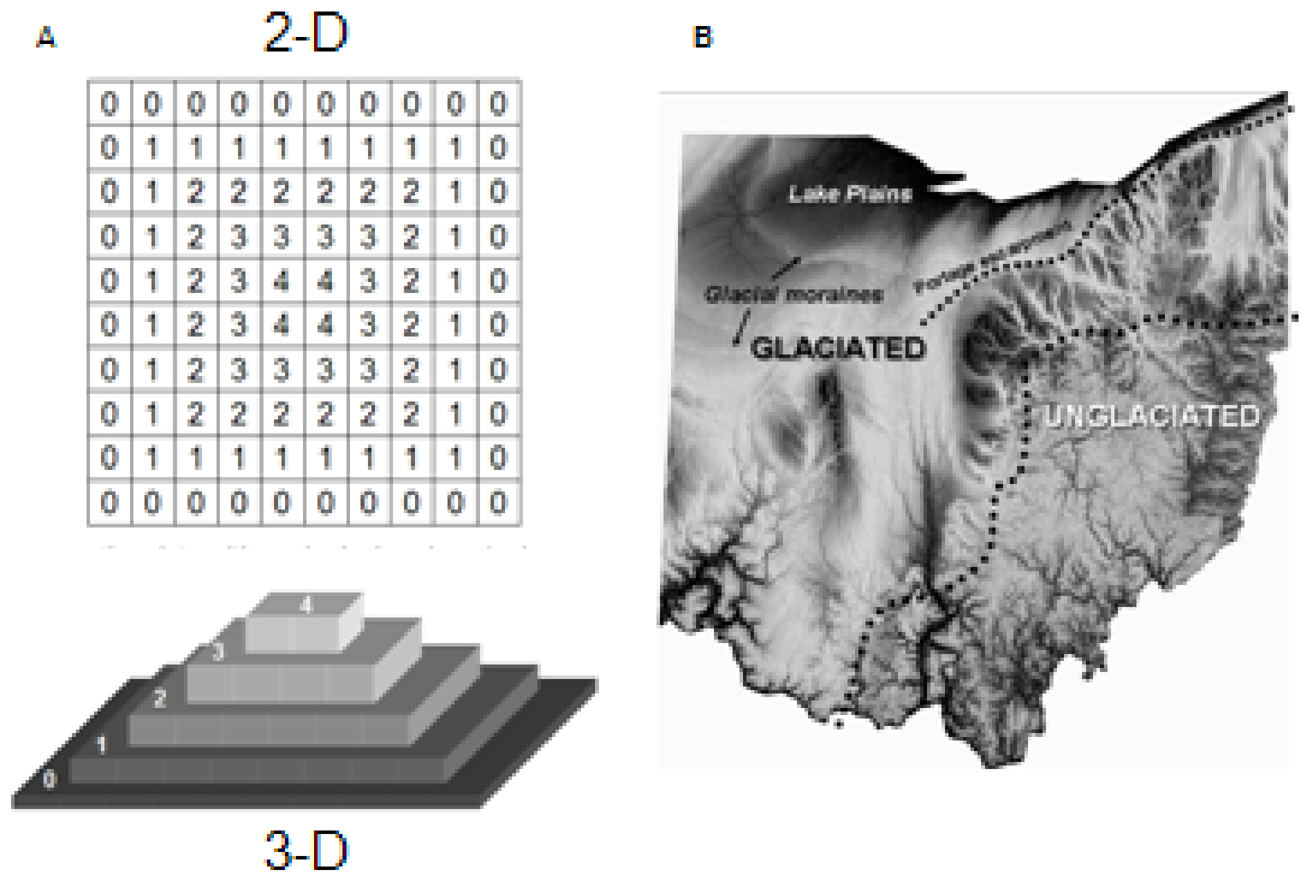

Figure *6A*. Conceptualizing a digital elevation model and how s 3-D model is constructed from a 2-D data grid. Fig. 6B. DEM of Ohio showing main physiographic regions and geomorphic features.

user could locate their house within GE, use GSU to take a snapshot of the house in the current view and design a new house in 3D, and finally, export their constructed house back into GE so that a user can interact with a fully detailed and textured 3D representation of the house (in the house's correct location). The use of spatial data, in conjunction with 3D visualization and design tools furthers teachers' understanding of GIS fundamentals and spatial concepts.

Digital Elevation Models (DEMs): DEMs are introduced in the context of understanding the topography of any region that may be studied. A basic overview and definition of a DEM is provided, and using a block model approach, the concept of a DEM is presented (Figure 6A). Teachers then spend time analyzing the topography of Ohio (Figure 6B) and through guided inquiry learn about the glacial moraines, and ice margins created during the last glaciation, the difference between glaciated and unglaciated areas, and the Portage escarpment that marks a change in geology, landforms, and weather.

Intensive Field Campaign - The SATELLITES Program was built on the premise that students need to experience science in order to understand it. Students are provided several experiences in conducting real science related to the environment. GLOBE (Global Learning and Observations to Benefit the Environment [a], n.d.), which is international in scope covering over 100 countries and over 16,000 teacher participants, engages students in the scientific process by requiring them to take careful observations following standard protocols, properly record the time and date, and record and archive the observations. Environmental observations are taken from the atmosphere (temperature, humidity, clouds, and precipitation), hydrosphere (water quality), biosphere (land cover, plant phenology, macroinvertibrates, and humming birds) and lithosphere (soil type, texture, temperature and moisture).

SATELLITES's approach is to engage students and teachers in short duration, local observation campaigns focusing on only a few types of observations, and development of student-led inquiry-based projects supported by university research programs. Teachers are trained to use GLOBE protocols in surface temperature, cloud type and cover, snow depths, and protocol for collecting data so that they can transfer these skills to students. An intensive but short period of data collection, as opposed to continuous data collection throughout the year, makes the project manageable in the classroom and has resulted in more schools reporting, sharing, and comparing data. SATELLITES training also provides the scientific context for why the observations are important as well as the skills of conducting an inquiry-based project that apply data collected from observations in a tangible, real world manner. Measurements center on the Surface Temperature Protocol developed by the founder of SATELLITES program (GLOBE [b], n.d.) . Surface temperature can be observed using an Infrared

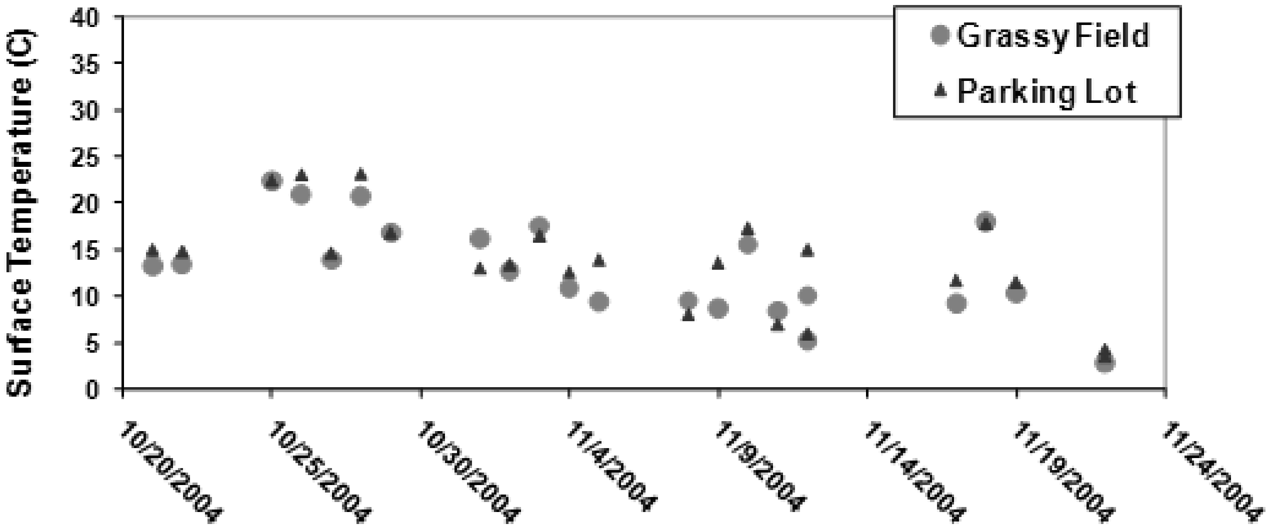

Figure 7. Surface temperature observations from Monroe High School, Monroe, MI from a field intensive in 2004 showing the difference in surface temperature for a parking lot compared to a grassy field.

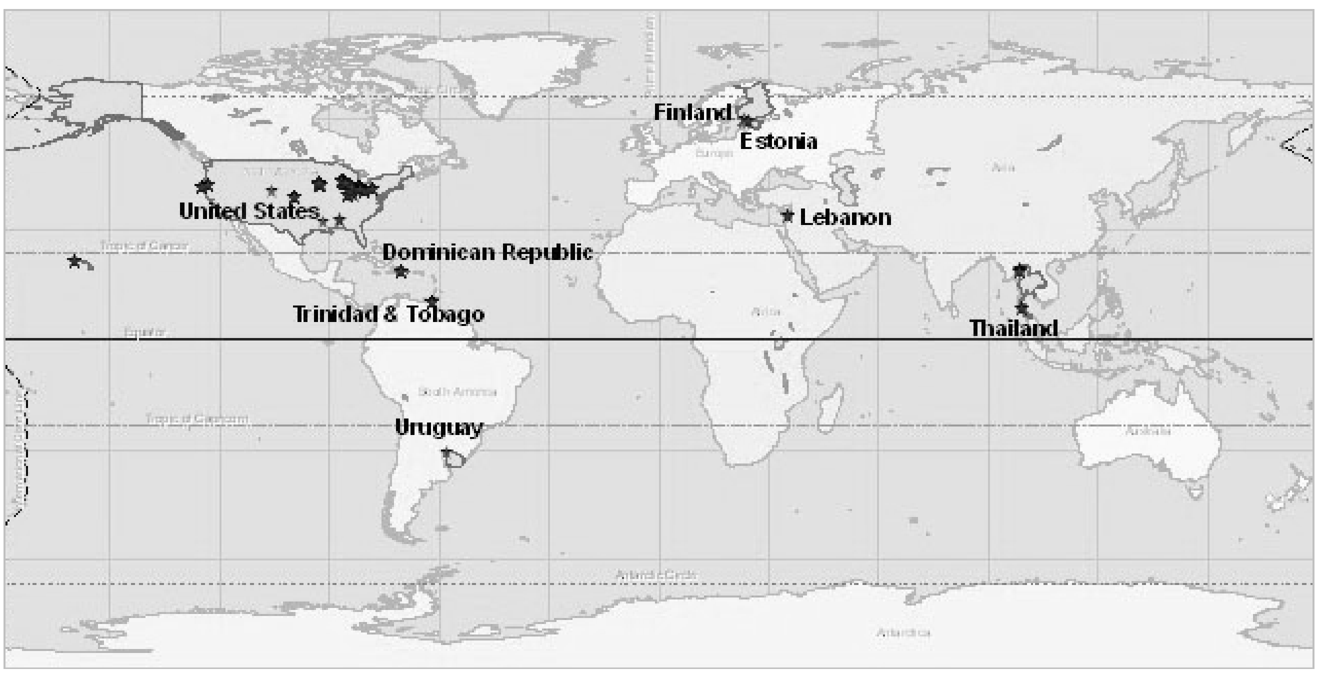

Figure 8. Schools participating in surface temperature field campaign (includes all GLOBE schools that participated, not just SATELLITES schools).

Thermometer (IRT) also known as non-contact thermometer and is the integration of the radiating temperature from ground surface features such as grass, bare soil, roads, sidewalks, buildings, trees, and snow in the instrument's field of view.

A requirement of SATELLITES is that teachers learn to take surface temperature observations of both a grassy field and a parking lot without cars in it and be able to scaffold their students during the school year while doing the same. Figure 7 shows that on most days the surface temperature of the parking lot is higher than that of the grassy field. On some days temperatures are the same, and while on other days the grassy field has a higher temperature. By observing cloud types, cloud cover and snow depth, teachers and students will be able to draw conclusions about the impacts of the land on the atmosphere even when using data collected only at local school settings. The most recent surface temperature intensive field campaign, focused on the International Polar Year. Forty-two schools entered nearly 1,200 observations worldwide. Over 250 teachers and their students participate in surface temperature observations worldwide with most of the schools located in Michigan and Ohio. However, observations are being taken in places such as Finland, Estonia, Trinidad and Tobago, Thailand and the Dominican Republic (Figure 8).

	Q.1 Geospatial Tech M (SD)	Q.2 Remote Sensing M (SD)	Q.3 Surface Temperature M (SD)	Q.4 Land Cover/ Energy Budget M (SD)	Q.5 Remote Sensing Apps M (SD)	Q.6 Five Types of Clouds M (SD)	Q.7 Digital Elevation Model M (SD)	Q.8 Inquiry-Based Project M (SD)
Pretest	1.50 (0.89)	1.90 (1.26)	2.08 (1.08)	1.78 (1.19)	1.55 (0.74)	3.03 (1.42)	1.15 (1.22)	2.45 (0.80)
Posttest	2.64 (0.58)	2.65 (0.74)	2.78 (0.62)	2.60 (0.78)	1.90 (0.38)	4.43 (0.71)	2.33 (1.05)	2.83 (0.50)
Score Change	1.14	0.75	0.70	0.83	0.35	1.40	1.18	0.38

Table 2. Change in mean scores on content knowledge assessment.

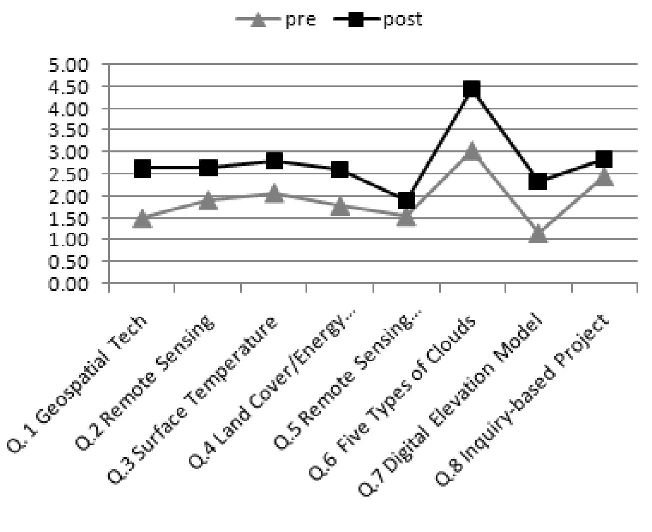

Figure 9. Pre and post test questions 1-8 from June and August, 2006 SATELLITES Institutes.

Inquiry Based Research Project - Although research says that students learn best when they complete inquiry-based projects (Krajcik et al., 1999), teachers still use direct instruction more often than inquiry approaches (McEwin et al., 2003). Based on conversations with classroom teachers who had participated in GLOBE observations, few of them use the observations in any meaningful way. Since the analysis of the observations, not the act of taking observations facilitates learning, an inquiry-based research project was incorporated into SATELLITES to offer teachers an authentic project to extend their GLOBE data observations. As a culminating experience in the Summer Institute, teachers were required to complete a small-scale inquiry-based research project. In learning the process for scientific inquiry, teachers selected a research topic; formulated a question/hypothesis; collected data from the GLOBE website, Landsat data servers, Google Earth©, as well as other ancillary web pages; refined their questions as needed; made graphs of the data; analyzed graphs and produced results; and drew conclusions about whether their analysis supported their hypothesis. Example research questions included "Does temperature change with topography?" and "Do different land covers heat up at the same rates?" Teachers presented their inquiry projects on poster board and were judged at the end of the workshop by (number of?) educators from different disciplines. This experience was intended to provide teachers with a model for implementing the inquiry-based project with their students during the school year.

As previously mentioned, completion of a similar classroom inquiry project with students was required for teachers to obtain the three university credit hours. During this project phase, teacher support was provided through email, on-site visits, and phone calls by project faculty. One of the main barriers teachers faced was the slow Internet connection in their classrooms as well as the lack of computers in some inner-city schools. Teachers were to train their students in collecting surface temperature data and posting collected data to the GLOBE web site during the fall campaign. This would provide students with valuable experience in collecting data, submitting data to GLOBE, and using the GLOBE website. Beginning in January until the end of March, teachers were to assist students in designing their own inquiry project based on GLOBE data following the Scientific Method. This would ensure that data were not only collected, but also analyzed. Students could form inquiry-based questions related to surface temperature or any other topic on which they could download datasets from the GLOBE website. They graphed the data, analyzed the graphs, developed results, and formed conclusions based on the analysis. Students reported their results on poster board just as teachers had done in the summer institute and presented these at the SATELLITES conference held at the Great Lakes Science Center in Cleveland, Ohio. Projects were entered into a competition with awards given to the highest-rated projects. 600 students attended the 2006 conference and 60 posters were presented and judged by OhioView scientists. Some of the projects included topics such as "Got Sun?," "Effect of Geographic Features on the Temperature of a Place," and "What Does the Snow Surface Temperature Have to be to Make a Good Snowfall in Alaska?" During the conference, students and teachers had the opportunity to network with the OhioView scientists and learn more about geospatial technologies and career opportunities.

PROGRAM EVALUATION

Forty-two teachers participated in SATELLITES summer institute including 27 females and 15 males. Of those, 35 teachers were White, one was Hispanic, and six were Asian. Two of the teachers taught in grades 4-5, five in grades 6-8, 24 in grades 9-12, and one in college. 37 teachers taught in some area of science, including Physical Science, Biology, Chemistry, Environmental

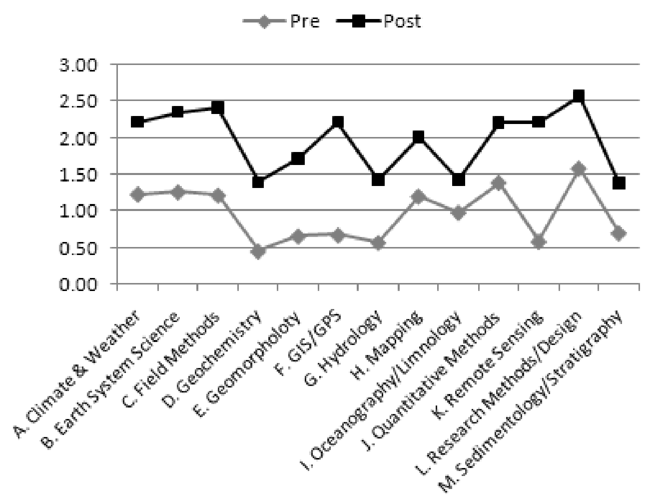

Figure 10. Pre and post self rating of experience on questions A-M from June and August, 2006 SATELLITES Institutes.

Science, Earth Science, Astronomy, Earth Space Science, General Sciences, Forensics, and Ecology. Two teachers taught special needs or gifted students, one in all subjects and one in the sciences. One teacher taught math; one Social Studies, Math and Language Arts; and one Computer Science. An objective of SATELLITES was to improve teachers' overall knowledge of the interdisciplinary uses of geospatial technologies, hence an assessment including questions in several different science disciplines. While it was expected that teachers would begin the Summer Institute with more content knowledge in topics related specifically to their science disciplines, it was anticipated that all teachers would have little knowledge about geospatial technologies. A two-part content knowledge questionnaire was developed by project faculty to assess teachers' knowledge of science concepts, scientific method, geographical topics, and geospatial technologies before and after the Summer Institute. The assessment was intended to measure prior knowledge level and amount of increased knowledge as a result of Institute training. Descriptive statistics are used to describe results.

The first part of the content knowledge assessment was comprised of eight short-answer questions related to weather, geospatial technologies, land cover and geography (available from the first author). Questions were rated by project faculty on a Likert-type scale between 0 and 5 with 5 being completely correct and 0 completely incorrect. Participants' scores were averaged on each question. Data from this part of the assessment are shown in Table 2.

Prior to training, teachers were most knowledgeable about the Five Types of Clouds [6] and in their ability to describe an Inquiry-based Project [8]. Teachers gained the most knowledge in naming Cloud Types [6] (M = 2.83, SD = .50), Surface Temperature [3] (M = 2.78, SD = .62), defining Remote Sensing [2] (M = 2.65, SD = .74), and Geospatial Technology [1] (M = 2.64, SD = .58). Knowledge increased on all other questions as well. While teachers could better define Remote Sensing [2] after training, they still knew very little about Remote Sensing Applications [5] (M = 1.90, SD = .38). Using a paired samples t-test, it was determined that the means on this section of the assessment were significantly different ($p < 0.00$). Figure 9 displays the results in graphical form.

The second part of the pre and post assessment asked teachers to rate their level of ability in 13 areas of science, science methods, and related technologies on a scale of 0-4 (0=no experience, 1=limited experience, 2=some experience, 3=proficient, or 4=expert). Figure 10 shows teachers' pre and post levels of experience on questions A-M. Prior to training, teachers were least experienced in Geochemistry [D] (M = .46, SD = .65), Hydrology [G] (M = .57, SD = .93), Geomorpholoty [E] (M = .66, SD = .93), and Sedimentology/Stratigraphy [M] (M = .71, SD = .99). They reported they had the most ability in Research Methods/Design [L] (M = 1.59, SD = 1.02) and Quantitative Methods [J] (M = 1.39, SD = 1.11). The geotechnologies, GIS/GPS [F] (M = .68, SD = .93) and Remote Sensing [K] (M = .59, SD = .81) were two other areas where teachers felt they had very little ability.

After training, teachers reported very little increased ability in Hydrology [G] (M = 1.40, SD = 1.01), Oceanography/Limnology [I] (1.40, SD = .81), and Sedimentology/Stratigraphy [M] (M = .1.36, SD = 1.04) as might be expected since these concepts were only minimally covered in the institute. The highest increase in ability was reported by teachers' in Research Methods/Design [L] (M = 2.61, SD = .74), Field Methodology [C] (M = 2.45, SD = .78), Earth Systems Science [B] (M = 2.40, SD = .72), GIS/GPS [F] (M = 2.28, SD = .72) and Remote Sensing [K] (M = 2.25, SD = .78). These were the areas that received the most concentration during the institute. While increases in ability were not statistically significant, they might tend to show that more training leads teachers to view themselves as more experienced in the areas of geotechnologies and related sciences. Increases in knowledge and ability to understand and use GIS/GPS, Remote Sensing, and scientific inquiry, teachers may be more apt to transfer their newly learned knowledge to the classroom even when not required.

After year-long participation in SATELLITES including the Summer Institute, implementation of student inquiry projects and the SATELLITES conference, teachers assessed their own confidence level and perception of ability to do inquiry science. Through questionnaires and written essays, teachers reported increased levels of engagement in students as they collected real world data using GPS and infrared thermometers and as they used the data in inquiry-based projects. One teachers wrote, "This inquiry-based instruction has allowed the students to work through a scientific process in an authentic situation that allowed students to work beyond their limitations. They identified their weaknesses and then discovered their errors. After identifying their errors they were able to correct them by beginning again and trying to accomplish their task in a different way." Increased engagement supports research showing that inquiry based approaches enhance student motivation particularly of minority urban students (Blumenfield et al., 1991; Patrick, 1990).

PEDAGOGY AND CURRICULUM STANDARDS

Classroom success can be attributed in part to SATELLITES' concentration on pedagogical methods. Through collaboration between faculty in higher education science, geography, and education, teachers are provided an integrated view of what it means to teach and learn science and time to reflect on their pedagogical content knowledge. Because teachers acquire much of their formal knowledge through undergraduate coursework in colleges and universities, these define the methods and content they teach to their students. University courses in methods of teaching science frequently emphasize technical skills and employ lecture methods rather than inquiry-based approaches (NRC, 1996). Therefore, it is critical that SATELLITES offers teachers in-service activities that model inquiry approaches and show teachers how real scientists conduct research. According to national science standards in professional development, learning activities should "involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding" (NRC, 1996, p. 59). Like science, geography standards focus on developing the life-long skill of thinking like a geographer and include the skills of asking geographic questions, acquiring information related to such questions, and organizing and analyzing the data in spatial ways in order to answer the questions (Geography Education Standards Project, [GESP], 1994). Through SATELLITES' inquiry-based activities and instructor modeling, teachers learn to think and act like scientist. These skills are transferred to the classroom as students are required to complete an inquiry-based research project.

SATELLITES also has found success with teachers due to the in-depth and challenging content connected to national and state curricula. The National Geographic Standards (GESP, 1994) encourage teachers to add new concepts, skills, and content to their curriculum and use creative approaches to teaching geography. They also advocate that in-service opportunities have clear connections to teachers' work and current curriculum standards in the context of the school. SATELLITES activities are interdisciplinary in nature but at the center of these activities are earth and space science and geography standards. Teachers receive a matrix of curriculum standards supported through SATELLITES activities and are provided yearly classroom support for integrating the new content and pedagogical methods in their instruction.

DISCUSSION AND CONCLUSIONS

With the projected growth rate of the geospatial job market combined with the lack of coverage geospatial technology receives in college textbooks, there is an urgent need to integrate geospatial technology into the academic curriculum long before students enter college. The SATELLITES program was established to provide middle-to-high school educators with much needed professional development in geospatial technologies and related areas of science. The primary goal of the program is to foster an understanding of the Earth and its environment and show how geospatial technologies can be utilized to analyze and affect that environment. Teachers receive training in a summer institute to use a variety of geospatial technologies and conduct scientific research.

Results from the 2006 SATELLITES assessment of 42 participants showed that teachers' knowledge of weather and climate, remote sensing, surface temperature, and geospatial technology significantly increased. The program also tended to increase teachers' self-reported ability in these areas as well as research methods and design, field methodology, Earth Systems Science, GIS/GPS, and Remote Sensing. However, while the program was able to effect significant increases in knowledge, because teachers did not have the prior content knowledge in the science topics covered, as evidenced by their low scores on the content assessment, knowledge levels even after SATELLITES training was still less than 50% accurate. Findings show the critical need for continued high quality teacher training in science, and particularly in sciences that utilize geospatial technology.

Another goal of the program is to ensure that teachers transfer their newly learned concepts and technologies to their classrooms. SATELLITES offers teachers training in inquiry pedagogical methods and three credit hours of university coursework to implement an inquiry-based project with their students in the academic year following the Summer Institute. Ongoing support in the way of visits by scientists, both faculty and graduate students, through email and phone follow-up communication, and by videoconferencing with SATELLITES participants helps to ensure that teachers are successful at implementing these projects. As evidenced by the increased number of observations collected in the program from the prior years, classroom support is an integral component of the program. Because SATELLITES is a grant-funded project, only new teachers can be accepted into each year's Summer Institute. However, teacher participants from prior years are notified through email of the next year's campaign. Of the 43 schools that collected observations in the fall 2006 field campaign, 13 had collected data in prior years. While this may not seem like a large number of return participants, voluntary participation by teachers in subsequent years shows the long-term effects that result from SATELLITES training. Even 13 returning teachers will influence and introduce hundreds of students to scientific research that utilizes geospatial technology and this was evidenced by the 300 schools from around the world that participated in the field campaign and 600 students who attended the annual SATELLITES conference. One of the future goals of SATELLITES is to find better methods of recruiting returning teachers.

The annual conference motivates students and generates an abundance of science questions from teachers and students as the event nears. This is evidenced by the fact that over 500 students attended the 2007 conference and presented 50 inquiry-based research project posters. Additionally, representatives in attendance at the conference from Kent State University, NASA Goddard Space Flight Center, and Ohio State government attest to the popularity and success of SATELLITES. As further evidence of the significance of the SATELLITES program, a representative from the State of Ohio and former Governor Strickland asked that project posters to be displayed in various government buildings in Cleveland during June and July 2007. Funding was procured to continue the program across Ohio in future years. In August 2007, a NASA International Polar Year grant provided funds to spread SATELLITES to West Virginia, Pennsylvania and Maryland.

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