Socio-Environmental Science Investigations: Hands-on Active Learning with Geospatial Technologies

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Abstract. We have developed, implemented, and evaluated a series of innovative socio-environmental science investigations (SESI) using a geospatial curriculum approach that has provided economically disadvantaged secondary students with technology-rich, spatial learning experiences to develop science data gathering and analysis skills. SESI are based on the pedagogical frameworks of place-based education and socioscientific issues-based instruction. Place-based education focuses on local or regional investigations, is designed around engaging students in examining local issues [1] and utilizes field-work to gather evidence in that local setting [2]. Place-based education connects learners to their immediate environment and can provide opportunities to empower students to address important socio-scientific issues in their communities. Socio-scientific issues are socially relevant, real-world problems that are informed by science and often include an ethical component [3]. They are sometimes controversial in nature, but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible issue resolution [4]. These issues require the use of evidence-based reasoning, and provide a context for understanding scientific information using an active approach to learning, placing science content within a social context in a way that supplies both motivation to and the ownership of learning by the student [4].

With SESI, students explore local issues through a sequence of inquiry investigations. During the investigations, students use iPads with built-in GPS utilizing a map-based data collection app (Esri's Collector app) to gather data outside their school. The student-collected data is then shared into a Cloud-based map service over the Internet. The collaboratively created data set is displayed in ArcGIS.com, an interactive Web-based GIS (or Web GIS), along with other important contextual georeferenced data for each investigation (for example land use type, tree density, ground surface type, city tree planted species, personal and property crime, and others). The Web GIS includes a suite of tools that students use to manage, query, and analyze the geospatial data. They use geospatial thinking and analysis skills for exploring spatial relationships in the data, and also critical thinking skills to synthesize, compare, and interpret georeferenced data to investigate problems in their local environment. Here we present two SESI

investigations: (1) Trees and Ecological Services, and (2) Urban Heat Islands.

In the Trees and Ecological Services investigation, students observe the different types of vegetation around their school and throughout the city to understand the environmental and societal benefits that trees provide to their community. In the first step of this investigation, students explore with iPads to identify and collect data on the trees that surround the school. Students use a tree dichotomous key iBook that they are presented with a series of choices about the characteristics of trees. Using the iBook, students characterize the main features of the trees (such as leaf shape, vein arrangement, types of fruits, etc.) by reading through a series of questions accompanied by displayed sample images. They use these features to identify the tree species and learn if trees are native or exotic species. Students also measure the tree circumference and estimate the tree height. Students' data are entered into a map-based data collection app (Esri's Collector app). After returning to the classroom, students view all collected data and compare their findings with a data layer of planted city trees provided by the local shade tree commission. Drawing on both sets of data, they are tasked with identifying tree planting patterns and thinking about benefits of planting shorter trees in certain city locations, for example, under power lines and other obstructions. The investigation then requires exploring the ecological services provided by trees (energy savings, air pollution removal, storm water catchment, carbon dioxide reduction, and aesthetics), and calculating a monetary value for these services for the trees surrounding their school.

Next, students examine neighborhoods in their own city—what social benefits do trees appear to provide? To simplify the task, we set up specific areas for investigation in the GIS maps used for the analysis: combinations of three city census blocks that contain variation in key factors, such as tree canopy cover and crime rate, to allow students to see how these factors are interrelated. Students are assigned a specific area on the interactive Web GIS map and must identify patterns in the percent of tree canopy cover (whether high or low), and personal and property crime rates (whether high or low) in that selected area. To investigate the relationship among trees and personal and property crime in their city, the entire class combines their collected tree data from across the student groups into a shared data table. Using these data, students identify the relationship between tree canopy and personal and property crime. While some students are able to detect the pattern immediately, we arranged the data table to allow the teacher to scaffold the process for identifying patterns and relationships among the different data layers. The pattern observed in this investigation is similar to those reported in Baltimore, USA and other cities where greener neighborhoods have significantly fewer crimes than non-vegetated areas [5]. However, correlation may not reflect causation, as there may be other mitigating factors at work.

A final motivating feature of the SESI activities is their social relevance to the students. At the end of the Trees and Ecological Services investigation, students apply their new knowledge to their local neighborhoods: *How can you improve your local neighborhood using the information you learned in this investigation?* Students are invited to take pictures to document their neighborhood and annotate the GIS map to suggest changes that will enhance the environmental and/or societal health in their community. Thus, the SESI investigations involve decision-making that is based on the analysis of scientific data connected to relevant social science content, and include implications for social equity and advocacy.

In the Urban Heat Islands SESI activity, students learn about heat absorption and re-radiation from different parts of the natural and built environment, culminating in proposed changes to neighborhoods that would reduce the heat island effect. The first step in the lesson is a presentation from the teacher about the scientific concepts involved: What is temperature and how do we measure it? What is the difference

between air temperature and ground surface temperature, and what are the sources of heating and cooling effects on both? What is a heat island, and why is it an urban phenomenon rather than a rural phenomenon?

After the content background presentation, students download a map of a sampling area to the Esri Collector app. Next, they move outside with GPS-enabled iPads and infrared surface temperature thermometers. Working in pairs or trios, students orienteer to an assigned zone on the school property where they obtain temperature readings from various surfaces found within their zone, including grass, dark and light asphalt, concrete, bare soil, and other surfaces they may observe.

Once back in the classroom, the data from the individual iPads are synced into a aggegated dataset. Next, the students work in groups to examine the collected data using ArcGIS.com and observe the patterns in temperatures recorded on different surfaces (for example, dark asphalt vs. light asphalt or concrete vs. grass), and under different conditions (shaded vs. unshaded or morning vs. afternoon). Using the Web GIS, students observe the contrasts between shaded areas, such as tree-lined areas along sidewalks, versus the hotter temperatures recorded in the middle of the parking lot. Students analyze data to understand temperature differences from sunlight absorbed and retained in dark asphalt surfaces over the course of the day. This analysis is used to reinforce concepts about heat absorption and re-radiation, and how albedo and shaded areas can reduce this effect.

In the next step of the investigation, students deepen their analysis using a GIS map of the land cover in their city. This map displays both built environment features (e.g., structures, roads, impervious surfaces such as parking lots) and natural features (e.g., vegetation and tree canopy, particularly trees that shade structures and roads) that help reduce the urban heat island effect. Working in groups, students focus on an assigned neighborhood in their city to examine the land cover and discuss how it contributes to the urban heat island effect.

After considering possible mitigation strategies, students propose several changes for their assigned neighborhood. For example, students have suggested creating shade by adding rows of trees within parking lots, converting dark rooftops to light-colored rooftops, modifying large commercial structures such as office buildings to incorporate green roofs, and have offered other recommendations that increase albedo and decrease solar energy absorption by a surface. Students then use the suite of draw tools to make these changes on their ArcGIS.com map and submit their recommendation electronically to their teacher.

Keywords: Web GIS, socio-environmental science, place-based education

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