The Implementation of Socio-Environmental Science Investigations Using Mobile Learning and Web GIS: Pilot Test Findings

Alec Bodzin[a], Thomas Hammond[a], Qiong Fu[a], William Farina[a], and Kate Popejoy[b]

[a]Department of Education and Human Services, Lehigh University, Bethlehem, PA, United States
[b]Popejoy STEM LLC, Whitehall, PA, United States

Paper presented at the 2019 National Association for Research in Science Teaching Annual International Conference, Baltimore, MD, USA, March 31 – April 3, 2019

Abstract

A series of novel socio-environmental science investigations (SESI) that use map-based mobile data collection followed by analysis with Web-based dynamic mapping software were developed and pilot-tested with economically disadvantaged secondary students. Results from qualitative data analysis of field observational data collected during the SESI investigations revealed that students were highly engaged with the GPS-enabled iPads for data collection. The majority of students stated in a survey that they would like to use more Web-based mapping applications in school. Quantitative data analysis for the pilot-testing did not show any significant mean changes ($\alpha = .05$) in pretest and posttest measures of students' interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies such as mobile devices and computers for learning. A major issue that arose during the implementation of the projects was a reluctance of many students to complete multi-part learning tasks and comprehensive writing tasks.

The NSF AC-ERE report (2015) *America's Future: Environmental Research and Education for a Thriving Century: A 10-year Outlook* stressed the importance of understanding the role of humans as drivers of environmental change and the effect of these changes on environmental and human well-being. These socio-environmental outcomes involve understanding how environmental protection and economic development complement each other. Education programs focusing on environmental issues can increase student interest and participation in science. Environmental issues have great societal relevance and many environmental problems have disproportionate impacts on under-represented and disadvantaged groups. Addressing issues pertaining to ecosystem function, urban heat islands, and the design of built environments requires important skills found in STEM workforce sectors. In addition to critical thinking and reasoning skills, science curricula train students to collect and analyze data, consider multiple hypotheses, solve problems and effectively collaborate and communicate – important skills that help prepare students for career opportunities and lifelong learning (National Research Council, 2011; National Science Board, 2015).

The U.S. Department of Labor has identified geospatial technology as a sector "projected to add substantial numbers of new jobs to the economy or affect the growth of other industries or are being transformed by technology and innovation requiring new sets of skills for workers" (National Geospatial Advisory Committee, 2012, p. 4). Despite accelerating industry growth and congruence across STEM, few school-based programs integrate geospatial technology within their curricula. Geospatial thinking and reasoning skills (GTR) are essential for occupations in which geospatial analysis skills for solving problems is either critical to the job or enhances occupational competence where there is a heavy reliance on cognitive thinking skills that include knowledge about geospatial relations and geospatial reasoning skills (Goodchild & Janelle, 2010;

NRC, 2006). GTR skills involve important scientific practices highlighted in the Next Generation Science Standards [NGSS] (NGSS Lead States, 2013), and include data manipulation, analysis, data mining, and modeling that provoke and require critical thinking and problem solving that are connected to data referenced to Earth's surface or to the Earth's representation through map and globe visualizations (Huynh & Sharpe, 2013). GIS is now the standard for spatially referenced data management, but STEM curricula often contain learning experiences that do not match the analytic practices that are critical for success in STEM-based occupations (Aikenhead, 2005; Chin et al., 2004).

Previous studies have confirmed that spatial ability, measured by visualization and reasoning tasks, is a significant factor in science subject achievement (Lubinski, 2010; Wai, Lubinsky, & Benbow, 2009). For many concerned with widening access to and involvement in the sciences, these findings are significant, especially since it is confirmed that gender plays a role in some spatial abilities (Voyer, Voyer, & Bryden, 1995). This has led to calls for explicit attention to improving spatial thinking skills in girls, including recognition that spatial skills are not innate but can be developed (National Research Council, 2006); encouraging young people to engage in learning activities that use spatial thinking skills (Hill, Corbett, & St. Rose, 2010); and using geospatial tools to promote critical thinking, analysis, and reasoning in problem solving (U.S. Department of Labor, 2010). A recent meta-analysis conducted by Utall et al. (2013) concluded that spatially enriched curriculum succeeds in increasing STEM performance and participation.

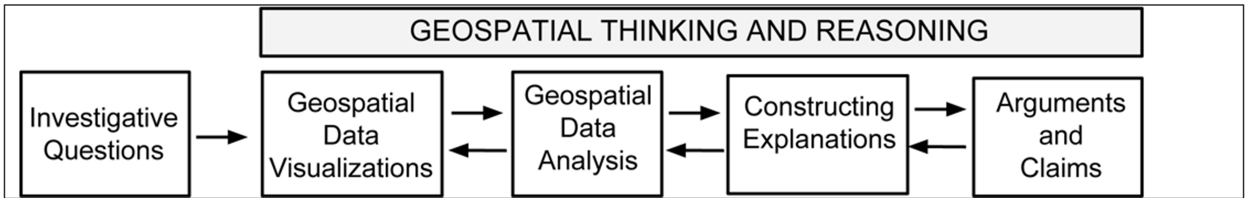
The use of GIS to spatially investigate Earth and Environmental sciences during classroom investigations has proven effective in the development of accurate scientific understandings about complex Earth and environmental science concepts with secondary learners (Bednarz, 2004; Bodzin & Fu, 2014; Bodzin, Fu, Kulo, & Peffer, 2014; Edelson, Pitts, Salierno, & Sherin, 2006; Kulo & Bodzin, 2013; National Research Council, 2006). Building on this work, we have developed, prototype-tested, and pilot-tested a series of novel socio-environmental science investigations (SESI) using a geospatial curriculum approach. This paper presents the results of the second year of our design-based implementation study. This pilot-test study focuses on urban students' perceptions of learning with SESI investigations. We specifically were interested in the following research question: *After the pilot-testing of the SESI investigations, was there any change in pretest and posttest measures of students' interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies such as mobile devices and computers for learning?*

Geospatial Curriculum Approach

Our geospatial curriculum approach for learning builds on our previous design work and the National Science Foundation's (NSF) Geotech Center's Geospatial Technology Competency Model (Bodzin, 2011; Bodzin et al., 2012; Kulo & Bodzin, 2013; Bodzin, Fu, Bressler, & Vallera, 2015). The curriculum approach incorporates design principles in each investigation to promote geospatial thinking and reasoning skills (see Figure 1). These principles include

(1) Use motivating contexts and personally relevant and meaningful examples to engage learners.
(2) Design image representations that illustrate visual aspects of social studies and Earth and environmental scientific knowledge.
(3) Design Web GIS data to make geospatial relations readily apparent.
(4) Scaffold students to analyze geospatial relations (Jonassen, 1999; Quitana et al., 2004).

(5) Develop curriculum materials that better accommodate the learning needs of all students, while also expanding the geospatial PCK of teachers.



Geospatial Science Technological Pedagogical Content Knowledge	**Earth and Environmental Science Content**	**Social Studies Content**
• Interactions between geospatial technology and pedagogical content knowledge to produce effective environmental science teaching and student learning. • Modeling geospatial data exploration and analysis techniques. • Scaffolding students' geospatial thinking and analysis skills.	• Human-Environment Interactions: Know and apply geographic information about relationships between nature and society. • Physical Geography: Know and apply geographic information about processes shaping the structure of the Earth's surface, physical landscapes, natural hazards, weather, climate, and atmospheric processes.	• Human-Environment Interaction: Place, Regions, and Culture • Human Population: Spatial Patterns and Movements

Geospatial Science and Analysis Skills

- Use GIS to manage, display, query, and analyze geospatial data.
- Use geospatial analysis to process geospatial data for the purpose of making calculations and inferences about space, geospatial patterns, and geospatial relationships.
- Use geospatial data analysis in which geospatial relationships such as distance, direction, and topologic relationships (e.g., adjacency, connectivity, and overlap) are particularly relevant.
- Use inductive and deductive reasoning to analyze, synthesize, compare, and interpret information.
- Use logic and reasoning to identify strengths and weaknesses of alternative solutions, conclusions, or approaches to problems.

Figure 1. Key components of the geospatial curriculum approach.

A primary goal of this curriculum approach is to develop geospatial learning activities in such a way that the software and hardware become transparent to the user. The initial geospatial data visualizations for our investigations are designed to be quick and intuitive for both students and teachers to use, thus decreasing interface issues that were reported by users of other GIS platforms (Baker & Bednarz, 2003; Bednarz, 2004). The learning activities include teacher support materials that use Web-based videos, text, and graphics to promote and support teachers' learning of important socio-environmental science subject matter and specialized geospatial PCK that they typically lack. Each learning activity is designed to include baseline instructional guidance for teachers and provide implementation and adaptation guidance for teaching a variety of learners, including reluctant readers, English language learners and students with disabilities.

We also employed a novel form of hybrid professional development (PD), with both face-to-face and online learning, in a design partnership model (Bodzin & Cirucci, 2009). Such PD approaches have been found to be effective in assisting teachers with the adoption of new curricula with spatial technologies in science classrooms (Bodzin, Peffer, & Kulo, 2012; Fishman et al., 2013; McAuliffe & Lockwood, 2014) because they offer teachers learning opportunities with geospatial technologies over a longer time period than a more common short-term summer institute. Our PD approach acknowledges that classroom teachers are pedagogical experts capable of adapting curriculum materials to meet the needs of their students (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). The PD includes active learning experiences by teachers, the opportunity to collaborate with peers, use of classroom-based instructional materials focused on SESI, the opportunity to reflect on teaching practice, and sufficient time to implement what has been learned (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007).

The SESI Investigations

SESI are inquiry-based investigations designed to take advantage of recent developments in powerful, mobile geospatial technologies to promote STEM-related workforce skills. The content of SESI focuses on social issues related to environmental science. The pedagogy is inquiry-driven, with students engaged in map-based mobile data collection followed by analysis with Web-based dynamic mapping software to answer open-ended questions. The investigations are multi-disciplinary, involving decision-making based on the analysis of geospatial data.

SESI activities are based on the pedagogical frameworks of place-based education and socio-scientific issues-based instruction. Place-based education focuses on local or regional investigations, is designed around engaging students in examining local problems (Sobel, 2004), and utilizes fieldwork to gather evidence in that local setting (Semken, 2005). Socio-scientific issues are socially relevant, real-world problems that are informed by science (Sadler, Barab, & Scott, 2007). Addressing them requires the use of evidence-based reasoning, and provides a context for understanding scientific information through an active approach to learning, while placing science content within a social context in a way that supplies both motivation to and the ownership of learning by the student (Sadler, Barab, & Scott, 2006; Zeidler & Nichols, 2009). Thus, the SESI investigations use authentic GIS data to investigate contemporary issues in local contexts, thus enabling learners to understand how local issues fit into larger regional and global issues (e.g., Atzmanstorfer, Resl, Eitzinger, & Izurieta, 2014).

The SESI investigations focus on students' immediate urban environment and connect the Next Generation Science Standards (NGSS) crosscutting concepts and scientific practices to disciplinary core ideas in Human Sustainability (NGSS Lead States, 2013). The investigations are designed for students to gather georeferenced data with GPS enabled iPads that are essential to each investigation, and place emphasis on social issues related to environmental science. The investigations require students to gather information relevant to their own communities. Students are then asked to take on the role of a decision-maker, and inform their thinking and reasoning about decisions based on their analysis of the data they gather, its connection to relevant social and environmental science content, and consideration of the implications for social equity and environmental sustainability.

Each SESI investigation focuses on a driving investigative question and specific content for implementation in a science classroom (ecosystem services, urban heat island), a social studies classroom (urban zoning, land use change over time), or both (healthy natural and built environment). Concurrently with this content learning, each investigation is designed to develop students' geospatial process skills. These skills include accessing different geospatial applications (Collector app on iPad and Web GIS maps on laptop computers), utilizing data collection procedures, displaying and navigating maps, annotating maps, analyzing data using different tools for pattern recognition and examining outliers, and constructing new data displays and visualizations. Appendix A includes a description of the SESI investigations and projects that were implemented during the 2017-2018 school year.

Methodology

Setting, Participants, and Context

The sample consisted of 149 students in the 9th grade in a high needs urban public high school in the northeast United States. The students attending this school are all economically disadvantaged—all students receive free breakfast and lunch. The sample included 77 males, 67 females, and 5 students that did not identify themselves with a specific gender. The race/ethnicity of the students included 90 (60.40%) Hispanic, 33 (22.15%) Multi-racial, 13 (8.72%) Black, 10 (6.71%) White, and 3 (2.01%) Others. Eleven (7.40 %) were classified as English learners and 23 students (15.40%) had IEPs. These students represent populations that are traditionally underrepresented in STEM-related fields (Connors-Kellgren, Parker, Blustein, & Barnett, 2016). Forty-seven students (31.5%) were identified by both the researchers and the classroom teachers as unengaged learners; they were unmotivated to learn, did not complete tasks, avoided challenging work, and did not seem concerned with achieving in school

(Sanacore, 2008).

During the 2017-2018 school year, seven socio-environmental investigations were pilot-tested. In addition, the students completed three geospatial projects that were prototype-tested during Spring 2018 with authentic assessment tasks to explore students' geospatial thinking and reasoning.

Measures and Analysis

Data for the following five measures were collected and analyzed to address the research questions.

1. Field observations conducted during the SESI investigations. Two researchers were present during the implementation of each SESI investigation and project. Field observations focused on student engagement, components of the investigations that promoted students' geospatial skills, and issues that arose during the curriculum implementation. Qualitative analysis was conducted for patterns of the observational data.

2. Student survey designed to measure perceptions of the SESI investigations. This survey, comprising three open-ended and four Likert-type questions, was administered to the students after they completed the ecosystem scavenger hunt, built environment scavenger hunt, trees and ecological services, urban heat islands investigation, tree planting investigation, and zoning investigation. Descriptive and qualitative analysis was conducted for patterns of the survey data. A copy of this survey is in Appendix B.

3. Spatial Learning Attitudes (SLA) Survey. This survey was designed to measure students' perceptions of using maps and technologies such as mobile devices and computers that use map-based imagery for learning. The instrument includes 9 Likert-type items that were scored with a five-point scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*), with the possible total scores ranging from 9 to 45. The evidence of validity was established by having the items reviewed by a panel of three researchers with expertise in geospatial learning in education. The reliability (Cronbach alpha) of the SLA instrument was 0.791 for the pre-survey at the beginning of the school year and 0.851 on the post-survey at the end of the school year. Meeting the unidimensional assumption for each separate Rasch analysis (pre- and posttest), having ordered category and threshold measures, Rasch person reliability (.81 for pre- and .84 for posttest assessments) and item reliability (.99 for pre- and .98 for posttest assessments) were both high. The SLA survey is in Appendix C.

4. STEM Career Interest Questionnaire (CIQ). This questionnaire was designed to measure students' STEM career aspirations in three dimensions: students' interest in, intent to pursue, and perception of science careers. The questionnaire was adapted and modified from Tyler-Wood, Knezek, and Christensen's (2009) STEM Career Interest Questionnaire that included 12 Likert items with three subscales. Our modified CIQ included 13 Likert-type items that are scored with a five-point scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*), with the possible total scores ranging from 13 to 65. The evidence of validity was established by having the items reviewed by a panel of three researchers with expertise in geospatial learning in education. Both principal component analysis and exploratory factor analysis resulted in a two-factor structure for this measure. The first factor (items #1-8) pertain to personal interest, support, and intent for science-related college and career. The second factor (items #9-13) pertains to perceptions of working in a science-related field. Table 1 displays the reliabilities (Cronbach alpha) for the entire measure and the two subscales at the beginning of the school year (pre-survey) and the end of the school year (post-survey).

A Rasch analysis was conducted and the dimensionality was consistent with the 2-factor structure. Rasch analysis on the first factor that pertain to personal interest, support, and intent for science-related college and career yielded Rasch person reliability.87 and item reliability .76. Rasch analysis on the second factor that pertain to perceptions of working in a science-related field found the Rasch person reliability (.77) was moderate, largely due to the limited number of items (only five) and the Rasch item reliability (.99) was almost perfect. A copy of the CIQ is in Appendix D.

Table 1

Pre-post Cronbach's alpha for entire and subscales of CIQ.

	(Sub-)Scale	Pre-survey	Post-survey
CIQ	Entire Scale (13 items)	α = .903	α = .927
	Personal interest, support, and intent (8 items)	α = .900	α = .938
	Perceptions of working in a science relate field (5 items)	α = .767	α = .716

5. Student Interest in Science, Technology and Geospatial Technology (STEM-GEO) instrument. This instrument was designed to measure students' interest in learning science, interest in using technology to learn science, interest in careers in technology, and attitudes towards geospatial technology. The measure was adapted from Romine et al.'s (2014) Student Interest in Technology and Science instrument that included 25 Likert items pertaining to students' ideas about learning science, careers in science and technology, and ideas about biotechnology. Our STEM-GEO instrument included 24 Likert-type items that were scored with a five-point scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*), with the possible total scores ranging from 24 to

120. The evidence of validity was established by having the items reviewed by a panel of three researchers with expertise in geospatial learning in education. Both principal component analysis and exploratory factor analysis resulted in a four-factor structure for this measure. The first factor (items #1, 3, 5, 11, 13, 14, 17, 18) pertains to interest in learning science and science-related careers . The second factor (items # 2, 4, 6, 7, 8) pertains to interest in using technology to learn science. The third factor (items # 9, 10, 12, 15, 16) pertains to interest in careers in technology. The fourth factor (items # 19, 20, 21, 22, 23, 24) pertains to attitudes toward geospatial technology. Table 2 displays the reliabilities (Cronbach alpha) for the entire measure and the four subscales at the beginning of the school year (pre-survey) and the end of the school year (post-survey).

The Rasch person reliability (.88) and item reliability (.98) were both high for the pretest measure data. The Rasch person reliability (.89) and item reliability (.95) both remained high for the posttest data. A copy of the STEM-GEO instrument is in Appendix E.

Paired-sample *t* tests of the pre-post SLA, CIQ, and STEM-GEO measures for the entire instrument and subscales were run to address the primary question on changes in the interests and perceptions in learning science, interest in STEM-related careers, and their perceptions of using map-based technologies such as mobile devices and computers for learning.

Table 2

Pre-post Cronbach's alpha for entire STEM-GEO and subscales.

	(Sub-)Scale	Pre-survey	Post-survey
STEM-GEO	Entire Scale (24 items)	$\alpha = .924$	$\alpha = .943$
	Interest in learning science and science-related careers (8 items)	$\alpha = .893$	$\alpha = .911$
	Interest in using technology to learn science (5 items)	$\alpha = .807$	$\alpha = .879$
	Interest in careers in technology (5 items)	$\alpha = .872$	$\alpha = .915$
	Attitudes toward geospatial technology (6 items)	$\alpha = .817$	$\alpha = .886$

Results and Discussion

Results from observational data collected during the SESI investigations revealed that students were highly engaged with the GPS-enabled iPads for data collection. During data collection, students traversed the school property and surrounding neighborhoods, and they commented on these outside-of-the-classroom activities. Students said they appreciated "the sense of exploration and freedom" and "that we had enough freedom to choose where we want to go and which points to plot." Using technology and mapping applications to log observation data was also a highlight. Over two-thirds of students (69.7%) said they would like to use mapping and ArcGIS more in school.

Students enjoyed working with others, classmates as well as adult mentors. Working in small groups seemed to be successful for the students. Using mentors from the community enhanced the classroom experience by guiding learning and keeping groups on task.

Data gathered from the survey that focused on students' perceptions of the investigations indicated that a large majority (92%) of students agreed that the investigations were clearly taught, and a few said they liked it because it was at their skill level. Almost all students evaluated themselves as being successful in learning how to use ArcGIS over the course of the school year, and only 5% said they were not successful. Almost half (45.5%) of participants said they were curious about jobs using mapping or ArcGIS.

Among the 149 students who completed the pretest measures at the beginning of the school year in September 2017, 113 students completed the posttest measures in May 2018. Attrition was 36 students (24.1%). Table 3 shows the descriptive statistics (means and SDs) and paired-sample *t* tests for summation scores of the pre-post CIQ, SLA, and STEM-GEO measures. No significant differences between pretest and posttest were found for each of the three measures, $p > .05$. That is, the pilot-testing of the SESI investigations did not result in any changes in students' interest in learning science, interest in STEM-related careers, and their perceptions of using map-based technologies such as mobile devices and computers for learning.

Table 3

Summation Descriptive Statistics and Paired-Sample *t*-Tests (N = 113)

Pair	Mean (SD)		*t*-test (2-tailed)		
	Pre	Post	*t*	*df*	*p* value
CIQ Pre-Post	39.96 (9.40)	38.50 (10.42)	-1.70	112	.092
SLA Pre-Post	29.08 (5.99)	28.85 (6.30)	-0.37	112	.713
STEM-GEO Pre-Post	78.81 (14.68)	76.83 (17.11)	-1.09	112	.077

A major issue that arose during the implementation of the projects was a reluctance of many students to complete multi-part learning tasks and comprehensive writing tasks. This became apparent to us after almost all students did not complete the first project that involved a proposal writing task. We then revised the format of the Culminating Project to have students submit their proposals as a presentation file to reduce the reluctance of students to complete a writing task. This resulted in 79 of 113 students (70%) completing this project.

The results for the CIQ, SLA, and STEM-GEO measures might be due to the fact that two projects (Built Environment and the Culminating Project) were implemented sequentially during the last six weeks of the school year. As noted above, the majority of students were reluctant to engage in detailed proposal writing tasks. Due to our development schedule, these projects were the last curriculum learning materials to be created. A different instructional sequence that would intersperse the projects throughout the academic school year may have provided different results. During Summer 2018, we discussed our data findings with the teachers during our professional development institute and we developed a more optimal curriculum sequence for better curriculum coherency that will be field-tested during the 2018-2019 school year.

Concluding Thoughts

This research project contributes to the knowledge base on science curriculum design and development with geospatially-enabled learning technologies including mobile learning applications and Web GIS. Educators have recognized that such geospatial learning technologies have the capacity to promote spatial thinking by enabling powerful visualization, analysis, and synthesis of georeferenced data to expand student understandings of science (NRC, 2006). Due to their interactive capabilities, both mobile and Web GIS offer new learning opportunities that change the ways in which students can explore, investigate and learn new Earth and environmental science subject matter through a more dynamic interface that takes advantage of an enhanced visual mapping interface. The findings from the field observations and the survey designed to measure students' perceptions of the SESI investigations highlighted that urban learners who are economically disadvantaged were engaged in using mobile and Web-based mapping applications for learning about socio-environmental issues in their community. However, students may struggle with the multi-step process of conducting a geospatial analysis and communicating their findings. Designers, teachers, and researchers must continue to collaborate in creating engaging, well-scaffolded instructional materials that guide students through the entire process of geospatial thinking and reasoning.

Acknowledgements

We wish to give special acknowledgement to Ian Hanson, Shannon Salter-Burghart, Robson Junior, James Carrigan, David Anastasio, Breena Holland, Dork Sahagian, and Sara String, our partners in this work. This material is based upon work supported by the National Science Foundation under grant #DRL-1614216. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Appendix A. The Implemented SESI Investigations

Investigation	**Description of Learning Activities**
Ecology Scavenger Hunt	In this investigation, students identify different types of natural and artificial objects around their school. They are introduced to the Esri Collector app for collecting data on a mobile device and ArcGIS Online analysis tools to visualize and analyze their observations.
Built Environment Scavenger Hunt	In this investigation, students identify elements of the built environment around their school and identify how they work as resources for the community. They also examine patterns in the locations of these resources.
Zoning	In this investigation, students investigate the area around their school and identify what type of zone they are in (residential, business, industrial, green space, etc.). They determine how zoning areas are distributed around their school and compare their observations with the official zoning map for their city.
Urban Heat Islands	In this investigation, students investigate the area around their school to identify different types of ground surfaces (asphalt, concrete, grass, dirt, etc.) and compare the heat radiation of these surfaces.
Trees and Ecological Services	In this investigation, students investigate the area around their school to identify different types of trees, explore the environmental and societal benefits that trees provide in their city, and investigate the relationship among trees and crime in their city.
Transportation Modes	In this investigation, students investigate the environmental impact of different types of transportation. They also compare travel time and distance between the same locations with different transportation types.
Carbon Sequestration	In this investigation, students measure the age of a tree, calculate the amount of carbon sequestered (taken up) by that tree during its life, and compare the amount of carbon sequestered by the tree to a typical American monthly carbon emission.

Tree Planting Project	In this geospatial project, students have been given a grant that will fund the planting of trees on the property of their school. They develop a proposal to plant trees in at least two different areas on the property of their school using at least two different species.
Built Environment Project	In this geospatial project, students use ARCGIS.com to analyze a variety of city data that includes government services, business, municipal zoning, housing, and demographic data in a city ward (section). They develop a proposal for the community needs of their ward to be environmentally, socially, and economically sustainable.
Culminating Project	In the culminating project, the city government is creating a new comprehensive plan for future sustainable development and is interested in smart growth. A primary focus of this project is for students to develop a proposal to make their neighborhoods more livable for its citizens, apply smart growth principles, and make their assigned city ward more environmentally sustainable.

Appendix B. Student Perception Survey

Think about the past several classes when you worked on the Zoning activities.

1. What did you LIKE MOST about the Zoning activities?

2. What is one thing you would CHANGE about the Zoning activities, and why?

3. What would you still like to know from the material covered in the Zoning activities?

4. Please circle your level of agreement with this statement: "The material in the Zoning activities was clearly taught."

   Strongly agree Agree Disagree Strongly disagree

This school year, you used mapping and ArcGIS online to complete several investigations, including the ***ecosystem scavenger hunt, built environment scavenger hunt, trees and ecological services, urban heat islands, tree planting, and zoning*** activities.

Thinking about the **MAPPING** you did in these projects, what is your level of agreement or disagreement with each statement below? (Circle only one per question):

5. I was successful in learning how to use Arc GIS online.
   Strongly agree Agree Disagree Strongly disagree

6. I would like to use mapping and ArcGIS more in school.
   Strongly agree Agree Disagree Strongly disagree

7. I am curious about what jobs or careers use mapping and ArcGIS.
   Strongly agree Agree Disagree Strongly disagree

Appendix C. Spatial Learning Attitudes Survey

In this survey, you will be asked to share your ideas about spatial learning. Spatial learning involves using maps and technologies such as mobile devices and computers that use map-based imagery for learning.

For each of the items, you will be asked to indicate the extent to which you agree or disagree with a statement. Your choices will always be one of the following five options:

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

The survey contains 9 items. Please mark one response for each statement.

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
1. I find it easy to see patterns and relationships among things.	○	○	○	○	○
2. Maps help me learn.	○	○	○	○	○
3. I am good at reading and interpreting phone app maps.	○	○	○	○	○
4. I am good at reading and interpreting paper maps.	○	○	○	○	○
5. I like reading and interpreting paper maps.	○	○	○	○	○
6. When I am thinking about a complex idea, maps, diagrams and pictures help me understand.	○	○	○	○	○
7. I like to use maps on a smartphone to explore my environment.	○	○	○	○	○
8. I like to use maps on a computer to explore information in maps.	○	○	○	○	○
9. I am good at using computer technology to learn from maps.	○	○	○	○	○

Appendix D. STEM Career Interest Questionnaire (CIQ)

We would like to know what you think about **careers in science-related areas**.

Keep in mind: This is a questionnaire, not a test. You will not get a grade, but your answers are very important because we wish to understand what you think about science-related careers. Please answer the questions truthfully and to the best of your ability.

Please indicate how you feel about each statement below. There are no right or wrong answers. Read each sentence and MARK THE CIRCLE that BEST describes how you feel.

	Indicate how you feel about each statement.				
	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
1. I would like to have a career in science.	○	○	○	○	○
2. My family is interested in the science courses I take.	○	○	○	○	○
3. I would enjoy a career in science.	○	○	○	○	○
4. My family has encouraged me to study science.	○	○	○	○	○
5. I plan to go to college or technical school to learn a science-related career field.	○	○	○	○	○
6. I will graduate with a college degree or certificate with a concentration in a science-related career field.	○	○	○	○	○
7. I will have a successful job and make contributions to a science-related field.	○	○	○	○	○
8. I will get a job in a science-related field.	○	○	○	○	○
9. Working in a science-related field would mean that I work with other people in meaningful ways.	○	○	○	○	○
10. People who use science in their careers make a meaningful difference in the world.	○	○	○	○	○
11. Working in a science-related field would be challenging.	○	○	○	○	○
12. I would like to work with people who make discoveries in a science-related field.	○	○	○	○	○
13. I would like to work with people who work in an environmental field.	○	○	○	○	○

Appendix E. Student Interest in Science, Technology and Geospatial Technology (STEM-GEO)

Student Interest in Science, Technology and Geospatial Technology (STEM-GEO) Survey

In this survey, you will be asked to share your ideas about science, technology, and geospatial technologies. For the purpose of this survey, we use these terms in the following ways.

Science represents fields of study that focus on exploring the natural world. Science-related disciplines include Earth and environmental sciences, biology, chemistry and physics as well as applied fields such as engineering.

Technology represents any electronic or computer-based devices or systems. Examples might include computers, tablets, mobile phones, augmented reality glasses, or the Internet.

Geospatial technologies are computer-based tools that display Earth's features with thematic layers. Geographic Information Systems (GIS) and Google Earth are examples of geospatial technologies. They have embedded tools that are used to examine patterns, linkages, and relationships with the data. Users can view, manipulate, and analyze rich data sets from local to global scales, using interactive digital maps.

For each of the items, you will be asked to indicate the extent to which you agree or disagree with a statement. Your choices will always be one of the following five options:

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

The survey contains 24 items. Please mark one response for each statement.

Section I: Ideas about learning. Items in this section present ideas related to learning and your experiences in school. Indicate the extent to which you agree or disagree with the following statements. Please mark ONE response for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
1. I enjoy learning science.	○	○	○	○	○
2. I enjoy using technology to investigate science-related problems.	○	○	○	○	○
3. I plan to take more science-related classes in high school.	○	○	○	○	○
4. Technology helps me learn science.	○	○	○	○	○
5. More time in the school day should be devoted to science-related learning.	○	○	○	○	○
6. Technology makes learning science more interesting.	○	○	○	○	○
7. I enjoy using technology to learn science.	○	○	○	○	○
8. More time in science classes should involve the use of technology.	○	○	○	○	○

Section II: Ideas about careers. Items in this section present ideas related to careers in science and technology. Indicate the extent to which you agree or disagree with the following statements. Please mark ONE response for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
9. I would be more likely to take a job if I knew it involved working with technology.	○	○	○	○	○
10. Having a job in a technology-related field would be interesting.	○	○	○	○	○
11. I would like to work in a science-related area.	○	○	○	○	○
12. I would like to get a job in a technology-related field.	○	○	○	○	○
13. I would like to work in a science-related field that uses technology.	○	○	○	○	○
14. I would like to work with people who solve science-related problems with technology.	○	○	○	○	○
15. I would enjoy a job that uses technology.	○	○	○	○	○
16. I will probably choose a job that involves using technology.	○	○	○	○	○
17. I would enjoy working in a science-related related field.	○	○	○	○	○
18. I would like to work in a science laboratory or field setting.	○	○	○	○	○

Section III: Ideas about geospatial technology. Items in this section present ideas related to geospatial technology. Indicate the extent to which you agree or disagree with the following statements. Please mark ONE response for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
19. Using geospatial technology (such as GIS) helps find solutions to problems in our world.	○	○	○	○	○
20. Geospatial technology is important for our society's development.	○	○	○	○	○
21. Using geospatial technology improves our ability to understand our community.	○	○	○	○	○
22. Geospatial technology is important for modern life.	○	○	○	○	○
23. Geospatial technology is useful for the problems of everyday life.	○	○	○	○	○
24. Using geospatial technology with gaming (such as Pokemon Go!) is useful for exploring my environment.	○	○	○	○	○