Chapter 2
Participatory Professional Development: Geospatially Enhanced Urban Ecological Field Studies

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2.1 Introduction

Urbanization trends of the past century show a dramatic rise in the size of cities worldwide. More than 300 cities have more than one million inhabitants, and 16 "megacities" have populations exceeding ten million. With increased urbanization of rural landscapes and densification of existing cities, greater pressure is placed on critical urban natural resources, such as watersheds, forests, and wildlife. These resources are critical to maintaining ecosystem health and to providing economic, civic, and public health benefits for metropolitan area residents (Grimm, Grove, Pickett, & Redman, 2000). At the forefront of ensuring that urban ecosystems are

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healthy and sustainable are the young people that live in cities. Unfortunately, all too often, students and their teachers are not provided with the necessary knowledge to understand and appreciate the ecological richness and value of cities. Many students lack the necessary scientific skills to understand how their actions impact local urban ecosystems, how they can improve and change their city's ecosystem for the better, and how healthy urban ecosystems benefit their own lives (Manzanal, Barreiro, & Jimenez, 1999). To date, the teaching of ecology in high school classrooms has primarily focused on the study of areas where there has been relatively minimal human intervention. For example, in their 2004 review of environmental science high school textbooks, the Environmental Literacy Council (2004) found that very few books critically examined urban ecosystems, the impact of cities on the environment, and the role that humans have had in creating, changing, and impacting urban ecosystems. With the goal of improving students' and teachers' understanding and appreciation of their local urban ecosystems, we developed and implemented an urban ecology education program that utilizes a number of geospatial technologies.

Geospatial technologies such as geographic information systems (GIS) have emerged over the last 15 years as one of the primary research tools used by environmental scientists; however, a disconnect exists between the research conducted by professional environmental scientists and how environmental science is taught in typical public school classrooms. Few students work with tools regularly used by scientists or pursue authentic inquiries using current scientific data, regional or global information, and available research tools (National Research Council [NRC], 2006); however, recently there has been a dramatic increase in the availability of relatively user-friendly geospatial and visualization technologies, such as MyWorld GIS, Google Earth, and ArcGIS Explorer, and access to scientific data for educators. The availability of these programs at lost costs has increased the potential for integrating geospatial technologies in classrooms.

In this chapter, our summer secondary science teacher training program, called the Urban Ecology Institute, will be described, along with the challenges and

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lessons learned on how to design an immersive professional development program to improve teachers' knowledge and use of geospatial technologies. To that end, we first describe why urban ecology is a scientific basis for our work. Next we describe our theoretical and conceptual foundations that guide our work which is followed by a general overview of our program including details of our summer institute and the three individual investigations in which students and teachers engage. In presenting our program, we describe the final iteration (as of this writing) of the structure program. Next we present the results of our research and evaluation efforts that lead us to our existing programmatic structure.

2.2 Scientific Framework: Urban Ecology?

Urban ecology has been called an important frontier for educators because the core skills and concepts integral to urban ecosystem education are well established in national and state science education standards (Hollweg, Pea, & Berkowitz, 2003). Thus, the field of urban ecology affords an integrated curriculum that combines the power of science *as a way of knowing* with the direct impact of active learning about and in service to the local community (Berkowitz, Nilon, & Hollweg, 2003). By developing science curricula around urban ecology constructs, students are immersed in relevant local and inquiry-oriented learning environments. This curricular strategy emphasizes both process and content, moving away from the "survey of the sciences" and "skill and drill" approach often found in traditional classrooms and textbooks, which, all too often, saps the excitement and curiosity from many urban students (Kahle, Meece, & Scantlebury, 2000). Lastly, using urban ecology as a framework involves students directly in data collection and engages them as active participants in improving their neighborhoods (Carter, 1997).

One of the most popular technologies used in urban ecology are geographic information systems (GIS), broadly defined as a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world (Edelson, Smith, & Brown, 2008). GIS models are integral to many scientific fields but particularly important to urban ecologists and environmental scientists as GIS can be used to analyze spatial information and develop solutions to problems. The technology allows one to ask fundamental questions about locations and relationships between objects. For example, one might explore how the urban environment and corresponding ecological services of a system change in response to environmental and sociopolitical conditions or identify and highlight patterns and relationships among disparate phenomena. With the current level of GIS and visualization technologies, it is now possible to combine these systems with computational modeling tools. These computer systems make it possible for urban ecologists to explore multiple potential solutions to problems by asking "what if?" questions and obtaining feedback that informs the decision-making process (Maguire, 1991). In these ways, geospatial tools support the practices of urban ecologists and thus potentially provide access to those practices for students and teachers learning about the ecology of complex urban relationships (Beckett & Shaffer, 2005).

Urban ecologists engage in a variety of practices to understand urban ecosystems. Their specific research approach considers that biogeophysical systems are tightly linked to the socioeconomic aspects of human life. Ecological systems are dynamic and shaped by forces that occur over long periods of time (presses) such as climate change, and short-term impacts (pulses) such as cataclysmic storms, tornadoes, or fire. Cities are studied as coupled human-natural systems. Given their holistic paradigm, urban ecologists tend to take a central role in trying to keep urban ecological systems sustainable through understanding the deep interconnectedness between humans and the natural environment (Alberti, 2008). Unlike traditional ecology which often attempts to understand an ecological system devoid of human interference and impact, urban ecology as a discipline embraces humans as a keystone species and tries to understand the impact that the human-built system is having on the environment and how these anthropogenic changes feedback on the forces and drivers that shape urban ecosystems. Thus, an urban ecologist collects data with the goal of understanding how to solve complex urban problems, both social and natural, by developing land-use plans, wildlife management strategies, and ecosystem service protections that function to simultaneously accommodate human needs and ease the burden on the natural places people use (for a review of the discipline, see Marzluf, 2008).

One approach urban ecologists commonly take is the development of data-driven models that allow them to visualize potential future scenarios, compare alternative scenarios, and describe implications of potential changes in the urban environment for both humans and the natural world. These findings are then communicated to stakeholders so that policy makers can make informed decisions about future development. In short, urban ecologists live at the intersection of social science, policy, and scientific research and through their expertise and interdisciplinary collaborations are well positioned to understand the unique problems facing urban areas today. As such, the field of urban ecology is nuanced and consists of multiple layers that make the use of geospatial technologies a critical tool to identify relationships and patterns between the various components of urban ecosystems. It is our hope that, through meaningful field study science projects, teachers will be able to use geospatial technologies to engage in the practices of urban ecology.

2.3 Theoretical Framework of Our Professional Development

2.3.1 Pedagogical Praxis

The theory of pedagogical praxis suggests that new technologies make it possible for students to participate in meaningful learning activities by serving as a bridge between professional practices and the needs of learners (Shaffer, 2004). In other words, new technologies make professional practices, previously only available after years of training, accessible to novices. This is perhaps no more apparent than with the rapid increase in the use of GIS and similar tools to explore the natural world. For example, Google Earth and Google Maps, two of the most well-known geospatial technologies, have enabled not just specialists to overlay data and to evaluate the relationships between objects, locations, and other types of data but have engaged the general public in performing simple geospatial analyses. With the emergence of these new tools, attempts have been made to engage teachers and students in becoming urban ecology scientists through the evaluation of the ecological, economic, and social benefits of green space for urban residents. To do this, our professional development program has been constructed around the typical practices of professional urban ecologists and informed urban planners. This latter point is critical because according to the theory of pedagogical praxis, successful learning environments depend upon the alignment of authentic professional practice (Beckett & Shaffer, 2005).

2.3.2 Participatory Learning

Our model for professional development has been jointly informed by Shaffer's theory of pedagogical praxis, described previously, and a participatory learning environment framework as described by Barab and his colleagues (Barab, Hay, Barnett, & Keating, 2000). Participatory learning environments have five characteristics: (1) they should be designed to engage learners in authentic science; (2) learners should be engaged in the "making of science," and not simply memorizing a set of ready-made knowledge; (3) learners should be engaged in participatory science learning activities with others who have less, similar, and more experience and expertise than themselves, supporting the emergence of collaborative group work, and not simply individuals working in isolation (Resnick, 1987); (4) learners should not be simply completing the task for some reward (e.g., grades, professional development points) but should be working toward addressing a real-world need that they have identified as important to themselves and to society (Savery & Duffy, 1996); and (5) learners should be working in participatory science and should be given the opportunity to participate in a professional community, not simply hearing about the work of other authentic science communities.

2.4 Participatory Science Teacher Development

Building from both the theories of pedagogical praxis and participatory learning environments, as well as the research base on what constitutes effective professional development (McClurg & Buss, 2007), the notion of a participatory learning environment has been extended to professional development by adding new categories to the model which is now called *participatory science teacher development*. Three additional categories have been added to the model. First, the model includes explicit opportunities to learn urban ecological content through the doing of authentic science and then through the teaching of that science to students. Thus, understanding of content is intertwined with the development of both good scientific and pedagogical practices. Second, the model includes ample opportunities to engage teachers in thinking about that teaching and how to implement the technology and tools with students. This idea builds off Shulman's (1987) recommendation that professional development should help teachers to think and reason about their teaching role. Shulman correctly pointed out that it is the subject matter knowledge and the associated pedagogical content knowledge that hold real challenges for teachers who must learn about an innovation and somehow convert their new knowledge into a pedagogical form. To that end, teachers must have opportunities to develop understandings of how students with diverse interests, abilities, and experiences make sense of scientific ideas and what they as teachers can do to support and guide all students in learning. Third, the model also includes ongoing opportunities for reflection, feedback, and sharing of challenges and ideas regarding teaching of both the content and the use of technological tools with students. That is, during the summer program, described later, there is regular group reflection time, as well as time for teachers to work with their peers, while students are engaged with other aspects of the program such as career development training. During this time, teachers evaluate how their students are doing in terms of learning the science and the technological components of the program.

Rather than just relying on the summer program, we also set out to provide just-in-time resources for teachers. As a result, we developed a rich set of digital materials that teachers could access including audio and video podcasts of content and technical troubleshooting. During the implementation phase, we soon found that most teachers relied upon the curriculum materials as their primary means of support and as such we began embedding a significant amount of professional development experiences within the materials themselves by emphasizing the educative components of the materials (Houle, 2007). These educative materials provided teachers with a variety of supports such as potential misconceptions, teaching strategies, field-based strategies, questions to ask students, and potential technological challenges to expect during the implementation of the materials. The goal of these supports was to help teachers develop flexible knowledge and make informed decisions about the adaptation and implementation of the curriculum materials at times when they most needed it, namely, during their planning periods. To evaluate the effectiveness of the participatory science teacher development program in improving

- Teachers' urban ecology content knowledge
- Proficiency with geospatial technologies
- Their ability to leverage these new skills to positively impact student learning

the driving research question for our summer professional development program has been: What effect do the project's professional development strategies have on the skills and content knowledge of participating teachers specific to conducting information technology-enhanced field studies?

2.5 Structure of Our Program

Davis and Krajcik (2005) argue that multiple forms of professional development are more effective than any one approach; consequently, curriculum materials, particularly those that are technologically rich, will be more effective when coupled with other forms of support. This program has evolved to include several different types of supports for teachers. First, an intensive summer program, referred to as the summer institute, is executed in which teachers are immersed in the doing and learning of urban ecology content through the use of technology. Second, just-in-time academic year workshops are conducted which are refresher learning experiences. Third, the curriculum materials are developed from an educative framework which embeds supports for teachers into the materials. The curriculum materials have incorporated three components with each lesson. First, the teacher version provides the structure and "how-to" of the lesson. Second, the student version of the lesson is distributed to the students by the teachers. Third, the teacher version of the student handouts provides potential student questions, potential student responses to teachers' questions, misconceptions that students may have, and key areas in which teachers should focus when evaluating student work.

Our initial summer program began with two major technology-enhanced projects. The first focused on bioacoustics (more detail below) and the second major project focused on urban trees and the use of GIS and computer modeling technology. Even though the basic structure of our program has remained the same with time for teacher training and then time for teachers to work with students, we added a third project after our initial year as we found that many of our participating teachers needed additional support either in the form of more scientific research skills, how to conduct a field study, or content background on urban ecology. In the following we describe the latest structure of our program based upon the data that we collected regarding the efficacy of our program.

The current version of our summer program consists of 4 weeks of instructional time for teachers and 2 weeks for students. The first week of the summer institute focuses on providing teachers with the skills and knowledge to conduct technology-enhanced field studies. Teachers start by learning about urban ecology and conduct preliminary field studies while learning about how the technologies support data collection and analysis. During the second week of the institute, teachers focus on a particular project: (1) Foundations of Urban Ecology, (2) Bird Bioacoustics, and (3) Urban Street Trees. Our program has been built around the model of having teachers with various levels of experience simultaneously traverse two parallel learning trajectories – learning urban ecology content and the technology that is used to support the scientific processes that undergird the field of urban ecology. Thus, we try to have teachers progress through the program starting with Foundations of Urban Ecology and culminating with the Urban Tree Project; however, many teachers over the 3 years of our work have, not surprisingly, chosen the project that best connects to what they intend to teach or are teaching during the school year.

Within each project, teachers conduct short investigations, while exploring in greater depth the science content and methods of data collection and analysis, using relevant technological tools such as GIS or Google Earth. During the third and fourth weeks, inner city middle and high school students attend the institute. The teachers then have the opportunity to apply what they have just learned and to use the corresponding instructional materials to help teach the students. Each teacher works with four or five students on a project during the last 2 weeks of the summer institute. This model provides teachers with an opportunity to both "act" as students walking through the projects and an opportunity to "try out," and often teach, material which requires teachers to use new content and pedagogical skills in a safe and supportive environment. The details of the current versions of the projects are described in the following sections.

2.6 Curriculum Projects

2.6.1 Project #1: Foundations of Urban Ecology: Google Earth and Data Representation and Wikis

Foundations of Urban Ecology is designed to be a gateway project for teachers either not familiar with urban ecology or not familiar with geospatial technologies. Foundations of Urban Ecology projects focus on using Google Earth to enter data regarding water quality, urban street trees, bioacoustics, and soil quality with the goal of looking for patterns. In essence, the participants in this project collect their own data and use it in combination with data collected by other groups to better understand the differences and similarities of the geographic distributions of health parameters for local urban ecosystems. In essence, during the summer the teachers were split into groups and each group would collect data such as water quality, soil quality, and temperature and enter that data into Google Earth which can then be viewed by other groups in the same project. By having all groups' data available for rapid viewing in Google Earth, it is possible to look for patterns and discern any potential relationships and trends in the data rapidly. Further, with Google Earth's ability to layer the information, teachers are starting to become familiar and comfortable with the concept of layering of data. By focusing on the use of Google Earth, teachers are eased into the use of geospatial technologies to explore and understand their environment.

In many ways this project was the most challenging of the three projects to design and implement. As this project needs to serve the dual role of helping teachers learn new technologies, field-research techniques, and the conceptual basics of urban ecology. This project, in year 2, focused on basic data collection and entering that data into Google Earth. Much of the data remained isolated to the participants in that project and, as such, was of limited value and teachers did not have an opportunity to see how their data compared or contrasted with other groups. In year 3, there was a significant increase on the use of wikis to collaborate and share data within and across the groups and to place data from the bioacoustics and tree groups within their Google Earth projects. In this way it was far more possible to develop a significantly more holistic view of the health and features of the field sites under study. The other change that occurred prior to year 3 was that for new teachers this project would be the first project in which they would enroll. This was especially important for teachers who were not comfortable with either the technologies or urban ecology field studies. In the future, they would then be able to transition to the more advanced projects. This decision enabled us to not only develop longitudinal relationships with teachers but also provided a trajectory for teachers who enter our program who are either new to science, new to urban ecology, or new to the use of technology in science teaching.

2.6.2 Project #2: Bird Bioacoustics

This curriculum project was sparked by recent research in urban bird communication and challenges students to explore how birds adapt their communication systems to deal with urban noise. In 2003, a landmark study published in *Nature* found that Great Tits (*Parus major*), a small songbird breeding within the Dutch city of Leiden, sang at a higher pitch than those in quieter locations (Slabbekoorn & Peet, 2003). The study was elegant, simple, and ripe for replication by student scientists. Recent studies have found that other species of birds are able to raise the pitch of their song (Wood & Yezerinac, 2006) or increase song intensity in response to urban noise (Warren, Katti, Ermann, & Brazel, 2006); however, little is known about how most local species deal with noise pollution in urban areas (Warren et al., 2006), especially with respect to individual variation in adaptive strategies. Leveraging this research gap, students explore the challenges of bird communication in their urban environments through posing researchable questions and collecting and analyzing data to address these questions. These data are made more powerful by the emerging consensus on the scientific and social processes that drive urban ecological systems (Shochat, Warren, Faeth, McIntyre, & Hope, 2006). Once students have collected their data in the field (a city street corner, a park, etc.), they upload their data to a computer and use RAVENlite, a bioacoustics analysis software package developed by the Cornell Lab of Ornithology (Charif, Clark, & Fristrup, 2003), to examine the spectrograms of their recordings (see Fig. 2.1). RAVENlite allows students to quickly view and visualize their data, evaluate their recordings, and explore

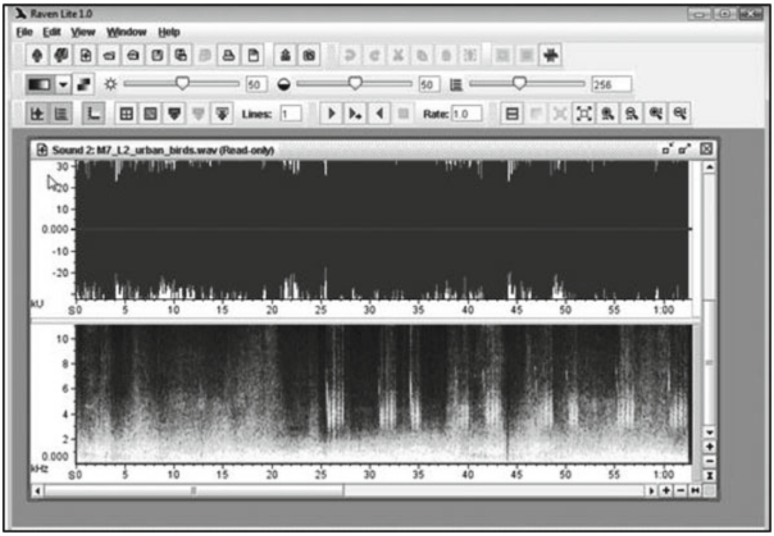


Fig. 2.1 Student audio recording of birdsong as viewed in RAVENlite

how urban noise in their city impacts birdsong, comparing their data with existing birdsong recordings. During the summer, the data that is collected is also shared with the Foundations of Urban Ecology group such that the data can be mapped in Google Earth. Following this analysis, students generate research questions, conduct additional research, and present their findings to their peers.

2.6.3 Project #3: Urban Street Trees: GIS and Ecological Impact

The Urban Street Tree Project capitalizes upon the increased recognition that city street trees have significant positive ecological impacts (McPherson et al., 1997). The urban street tree inventory is conducted using tablet PCs and CITYgreen, a software package developed by American Forests that plugs into the geographic information systems (GIS) software package, ArcView. CITYgreen is a personal computer desktop-based software application for comprehensive urban ecology benefit analysis and environmental modeling (UEAM) using high-resolution satellite and aerial photography images. The CITYgreen application is designed as extensions to the Environmental Systems Research Institute (ESRI) software platform of geographic information system tools ArcView and ArcGIS, which are GIS industry standards. CITYgreen was originally designed to allow city planners to

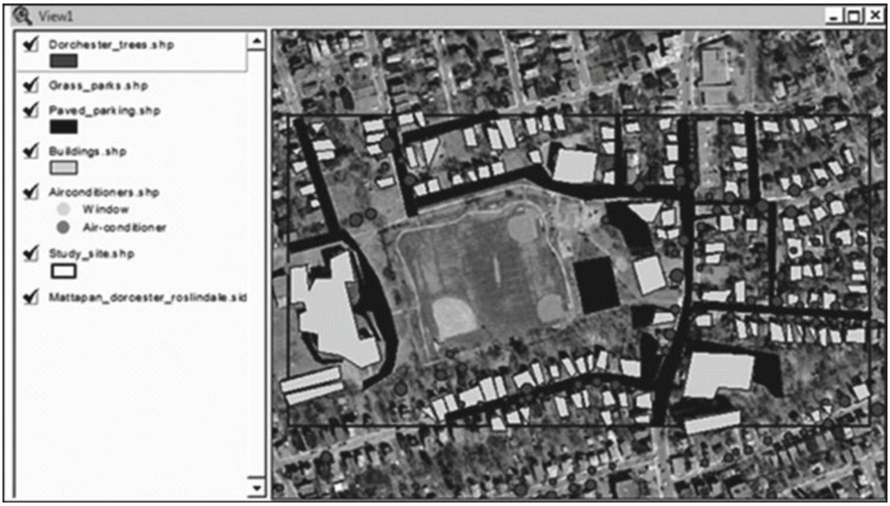
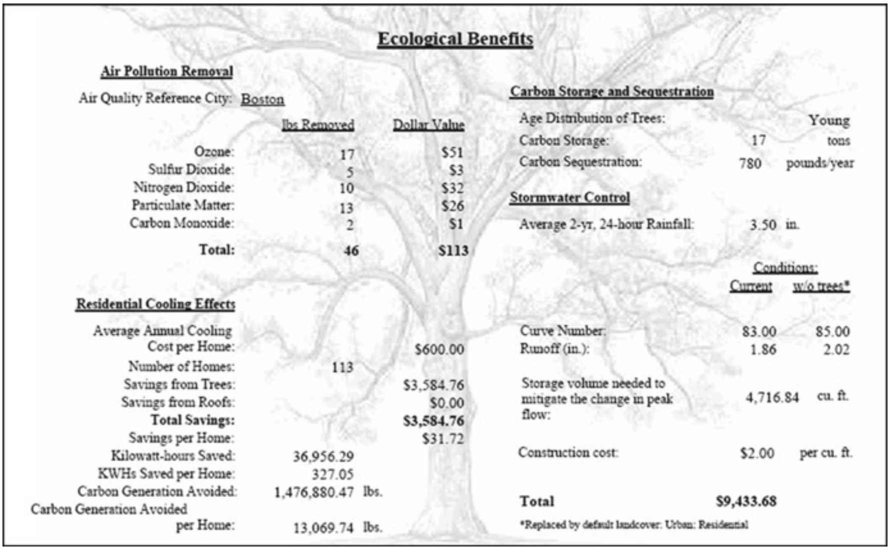


Fig. 2.2 Placing of trees and other land cover uses in CITYgreen

evaluate the ecological and economic green space in their cities (see http://www.americanforests.org/productsandpubs/citygreen/ for a more in-depth description of CITYgreen); however, teachers have been among the prime users of CITYgreen, because CITYgreen allows students to connect computer modeling and real-world data collection in order to conduct tangible, meaningful projects and make useful recommendations.

Students and teachers collect data on tree location and condition and use CITYgreen to evaluate the economic value of street trees on such outcomes such as storm water runoff, energy savings, and air pollution removal. The students can also evaluate the impact of street trees on air quality and the rate of carbon sequestration and determine how much carbon is stored in their urban street tree sample; however, what is perhaps most powerful about this project is that once students have collected their data (or used data from an existing street inventory for a given neighborhood, schoolyard, or park) and conducted an initial baseline data analysis, they can then ask "what if" questions. For example, in the city of Boston, there has been significant news coverage of the "Big Dig," a decadelong road construction project in which the city has diverted the major interstates that were running through city into underground tunnels and is currently in the process of converting the reclaimed land into green space. Through the use of CITYgreen, students can now model both the economic impact and the ecological benefits of the Big Dig. In another example, students can explore the impact of planting trees around their own school or neighborhood and evaluate the impact on the school's energy savings over time (see Fig. 2.2 for a screenshot of CITYgreen and Fig. 2.3 for a report). This latter



Ecological Benefits

Air Pollution Removal

Air Quality Reference City: Boston

	lbs Removed	Dollar Value
Ozone:	17	$51
Sulfur Dioxide:	5	$3
Nitrogen Dioxide:	10	$32
Particulate Matter:	13	$26
Carbon Monoxide:	2	$1
Total:	**46**	**$113**

Residential Cooling Effects

Average Annual Cooling Cost per Home:		$600.00
Number of Homes:	113	
Savings from Trees:		$3,584.76
Savings from Roofs:		$0.00
Total Savings:		**$3,584.76**
Savings per Home:		$31.72
Kilowatt-hours Saved:	36,956.29	
KWHs Saved per Home:	327.05	
Carbon Generation Avoided:	1,476,880.47 lbs.	
Carbon Generation Avoided per Home:	13,069.74 lbs.	

Carbon Storage and Sequestration

Age Distribution of Trees:		Young
Carbon Storage:	17	tons
Carbon Sequestration:	780	pounds/year

Stormwater Control

Average 2-yr, 24-hour Rainfall: 3.50 in.

	Conditions: Current	Conditions: w/o trees*	
Curve Number:	83.00	85.00	
Runoff (in.):	1.86	2.02	
Storage volume needed to mitigate the change in peak flow:	4,716.84		cu. ft.
Construction cost:	$2.00		per cu. ft.
Total	**$9,433.68**		

*Replaced by default landcover: Urban: Residential

Fig. 2.3 An example CITYgreen report showing the ecological value of urban trees

Fig. 2.4 Tree canopy in 20 years

investigation is possible because CITYgreen allows students to model tree growth over time, with sophisticated species- and tree-age-specific modeling algorithms, which enables them to evaluate what their urban street canopy will look like in 10 years, 20 years, and so on under alternative planting regimes (see Fig. 2.4).

2.7 Findings and Discussion of Our Research and Evaluation

2.7.1 Study Context

Our professional development program is intended to support teachers in continuous learning of both urban ecology content and technology used to carry out urban ecology science investigations. Although our program is now designed so that teachers should progress from the simplest technological project, Foundations of Urban Ecology, to the most technologically challenging, the Urban Tree Project, teachers often chose to participate in the project most aligned with what they intended to teach in the future. At the time of this writing, we have data from the first three summer sessions; however, in year 1, the reliability of our research instruments was quite low and as a result we will not present the results here (although we did use the results internally for improving our program). In addition, in year 1 the Foundations of Urban Ecology project did not exist. Therefore, for the purpose of presenting the outcomes of our program, we focus our description on year 2 and 3 of the summer program as the data from those 2 years provide the best insights into what has worked well and what aspects of the program was less successful.

2.7.2 Methods: Data Collection and Sample

The major goals of our summer program have been focused on improving teachers' understandings of student career development and improving their knowledge and confidence in conducting urban ecological investigations. To evaluate the efficacy of our program, we have been conducting pre-post surveys and focus group interviews with teacher participants. The summer pre-post "test" or assessment consisted of multiple scales (see Table 2.1) ranging from career knowledge and preparedness to scientific-inquiry beliefs. In Table 2.1 we present the four areas that we were interested in evaluating, the scales and a corresponding description of the scales, and the number of items in each scale. In Tables 2.2 and 2.3, we present the survey results from year 2 to year 3, respectively. Although we have conducted research on teacher understanding of STEM career development, we focus our discussion on inquiry science, learning and teachers' technology use, and their perceptions regarding their ability to use technology in their teaching.

Table 2.1 Scale reliabilities for the pre-post teacher surveys

Domain	Scale description	Cronbach's alpha (year 2)	Cronbach's alpha (year 3)
Science learning and teaching	Educators' self-efficacy in teaching science field investigations (comfort with site selection, managing students, and equipment outdoors)	0.927	0.818
Technology use	Educators' attitude about the usefulness of IT to engage students with scientific content	0.932	0.920
Inquiry science	Educators' self-efficacy in teaching students to formulate scientific explanations, models, and arguments	0.967	0.954
	Educators' self-efficacy in teaching students to design and conduct scientific investigations	0.986	0.974

Table 2.2 Year 2: Self-efficacy and other attitudes regarding career education, science teaching, and technology use

	Pretest scale scores		Posttest scale scores		
Scale name (N = 21)	*M*	*SD*	*M*	*SD*	t-value
Self-efficacy teaching field investigations	3.79	1.10	4.28	0.58	2.17*
Technology use	4.09	.75	4.38	0.45	2.72*
Formulating explanations, models, and arguments	3.88	1.04	4.32	0.61	2.46*
Designing and conducting investigations	3.72	1.17	4.32	0.60	2.88**

*$p < .05$, **$p < .01$

Table 2.3 Year 3: Self-efficacy and other attitudes regarding career education, science teaching, and technology use

	Pretest scale scores		Posttest scale scores		
Scale name (N = 19)	*M*	*SD*	*M*	*SD*	t-value
Self-efficacy teaching field investigations	4.36	0.55	4.66	0.37	−3.01*
Technology use	4.42	0.64	4.49	0.62	−1.27
Formulating explanations, models, and arguments	4.34	0.37	4.39	0.42	−.45
Designing and conducting investigations	4.44	0.45	4.59	0.34	−1.38

*$p < .01$

2.8 Findings and Discussion

2.8.1 Overall Findings

Across the last 2 years of our program, we found that, generally, participants in our program improved in their knowledge and skills in urban ecology and their perceptions of their ability to teach science through the use of geospatial technologies.

2.8.2 Year 2: First Year of Three Projects

We found statistically significant levels of skill improvement in teachers' skill with classroom uses of technology (teaching students to use technology, helping students to use technology in class as part of a lesson, and designing lessons that make use of technology to teach science) and their use of software tools specific to the summer institute (bioacoustics and GIS software). This finding was supported by focus group data as some teachers also mentioned being introduced to or improving their skills with specific technologies, such as GIS or Google Maps, whereas others specifically mentioned that they gained practice in explaining to students' software that they already knew how to use. What was perhaps most important thought was that several had begun thinking about new ways to use technology in their work. "I feel comfortable enough to begin to work on developing a course in GIS for science students," said one teacher. Unfortunately due to space limitations, the details of teachers' implementations will be reported elsewhere.

In terms of content knowledge, participants demonstrated improvement in their ability to define the term "urban ecology" with more complexity, recognizing physical, biological, and human components to urban ecology, but remained consistent in describing the primary benefit to society of studying urban ecology as helping solve urban problems and improve urban planning. The focus groups revealed that participants, in general terms, confirmed that their urban ecology content knowledge had increased during their 2 weeks of work with the students. Several gained a clearer understanding of urban ecology as a science and they reported learning specific content, such as identifying birds or trees. Others cited improvement in skills such as using water and soil test kits, collecting data, or using technology.

2.8.3 Year 3: Moving Toward a Final Iteration

In year 3 we used the same pre-post teacher survey used in Year 2 with a few additions. Generally we found there were statistically significant increases in participants' self-reported levels of skill with two of the software tools specific to this year's summer institute, bioacoustics and Wiki software. Teachers' skill with the third featured software tool, GIS, did not increase significantly. We suspect this was because the teachers had seen this technology in the previous years and as such we have begun to ramp up the sophistication of our GIS beginning with the integration of CommunityViz (http://www.communityviz.com/) for more complex modeling of urban planning contexts.

In terms of content understanding, there was no statistically significant change in any of the five ratings showing participants' level of sophistication about urban ecology content. Given that we had several repeat teachers in the program, we suspect that we experienced a ceiling effect which also has suggested that we are succeeding in raising teachers' knowledge and skills with GIS which further suggests the integration of more complexity. However, in participants' definitions of urban ecology (UE), we saw an increase in the number of people who mentioned the human, biological, and physical components of this discipline, noted the importance of interactions among factors, and referred to urban ecology as a study or science.

In terms of conducting field studies, which has historically been a major stumbling block for many teachers in doing environmental science activities, we found statistically significant changes over the course of the summer institute in their self-efficacy in teaching science field investigations. The major difference between year 2 and year 3 was that most respondents said that the time spent with students during the last 2 weeks of the summer institute was useful in helping them to better understand how to conduct a field study. However, a few felt that working with a small group of self-selected students was not realistic practice for actual classroom conditions. We suspect that this later belief came from the bioacoustics group where there were some challenging social and cultural dynamics between the teachers, the teacher leaders, and the students. This latter speculation seemed to be confirmed during the focus groups when the teachers reported that the urban tree group had especially effective student-leaders and cooperative student-participants this year, while in the bioacoustics group, certain social tensions among students affected the work.

2.8.4 Curriculum Implementation During the Academic Year

We observed and interviewed 13 teachers who implemented their chosen modules with anywhere from one to five class sections during the school year, with class sizes ranging from eight to more than 30 students. Three teachers had seventh or eighth graders; three had ninth, four had twelfth, and three had mixed or ungraded classes. Two teachers had special education classes, one had English Language Learner (ELL) classes, and one taught in a school where students were grouped by language competency; other teachers did not describe any special student characteristics. Overall, teachers felt the modules had worked well, though not flawlessly. The most frequent barriers to implementation were limited access to technology and time constraints. In turn, these barriers were often the key drivers of the modifications that teachers made to the unit. Although hands-on work with the software was a key component of each of the modules, many of the teachers had problems making that happen for their students primarily due to technical issues. During the academic year, our teachers have experienced technical problems such as not (1) being unable to install the software on their computers, (2) having sufficient computing capacity (particularly in our urban school settings), (3) having the time to learn how to troubleshoot technical issues within ArcView, and (4) having sufficient technical expertise to customize the software to meet their specific needs. In fact, in interviewing our teachers who used GIS technologies in their classroom, a common issue that arose was expressed succinctly by one:

> The potential for this [GIS based] project is immense. The students loved working on the project and learning the technology. We spent so much of our time trying to figure out what went wrong with the technology. I'm fortunate in that I have some time to play around with it, but I don't know how other teachers can use this as they simply won't have the time to learn the technology.

In addition to the lack of resources, another issue that arose during classroom implementation was unexpected technical trouble. Despite the fact that most of our teachers became comfortable with using the technology with their students during the summer and follow-up workshops, given the sophistication of the geospatial technologies, it proved to be very difficult to troubleshoot problems, which often leads to the loss of instructional time. For example, on several occasions a student would simply hit the wrong button in ArcView and cause some change to occur, but that change either corrupted their project files or changed their project files that resulted in errors when they attempted to run CITYgreen. This unexpected and difficult to predict challenge has led us to develop "troubleshooting" pathways for the most common errors and "points of trouble" for teachers, and we are embedding these into our program and the curriculum.

In evaluating our professional development program, we have also learned the value of providing a developmental pathway for teachers that slowly ramps them up in terms of their geospatial technology skill levels. The following teacher excerpt illustrates this point:

> I'm so happy that I didn't start with the tree project. I really needed to learn just learn about Google Earth and the idea of layers and how to input data. Then I could learn more about themes in ArcView. I think this just helped me to be less intimidated.

This idea of a gradual pathway took some time to implement as our program was designed to allow multiple entryways for teachers into learning about geospatial tools. As a result, our project team has experienced a continuous tension between providing a more structured trajectory for teachers versus allowing them the freedom to choose where they wish to start in the program. The latter option provides teachers with more ownership over their own development; however, it requires significantly more effort on behalf of our project team to support a teacher if their technological knowledge is low and they wish to participate in the more advanced GIS-based aspects of our program, and based upon our third year results, we are starting to expand our program to include more sophisticated GIS and geospatial technologies.

A particularly interesting finding was that teachers reported that their classes seemed evenly divided with regard to what engaged them most, the field work or the computer work. Almost all teachers said their students "loved" the technology; however, we think that a major strength of the curriculum was the strong connection between the students' real-world data collection and their in-classroom modeling and analyses of that data. This was pointed out by one teacher:

> You know the technology is fantastic. You can do so much, but you know what I think is most powerful about the project? I think it is that the students are collecting their own data and then using CITYgreen as a way to analyze their data. The students are given their data like so many other GIS based materials but they have to decide what to collect, where to collect, and then evaluate their data. I think this is what I like best about the project; it doesn't take data ownership away from the students.

That said, there was considerable variation in teacher assessments of whether or not the unit had helped students understand the scientific-inquiry process, and to some extent, their answers seemed to demonstrate differences in their understanding of the question. For example, one teacher described his/her students mastering several critical steps of a scientific investigation: "thinking about what a testable question is," "seeing if the data supported their hypotheses," and "using a model." Another described the use of a hands-on process to examine phenomena and to problem-solve: "They had to think a lot when they were outside. I gave them a number of trees; they had to identify them, see if they were healthy or unhealthy, [figure out] good places to plant." Other teachers reported that the project was more structured and they did not describe the project as inquiry for the students. They did, however, describe the student work as extremely important because it caused them to analyze their own data and to think about research questions even if the process that they (the students?) went through was highly structured. As we explored this issue in more depth with teachers, we began to notice that those teachers who had implemented the project for more than 1 year were more focused on the inquiry components of the project rather than on the technology. In fact, we have observed that teachers who had implemented the project over the 3 years of the grant have shifted from a more technological and rather structured pedagogical approach to a more open-ended inquiry approach, shifting from focus on the use of the technology to a focus on the science with the technology as a part of their instructional toolkit.

2.9 Implications and Closing Thoughts

Firsthand experience with conducting scientific inquiry, gaining proficiency with high level, professional grade technology, and introduction to the burgeoning field of urban ecology can provide students with the twenty-first century skills required for functioning in an increasingly technological society. Several research and development studies have found that GIS has the potential to provide students in all grades with a rich, inviting, and challenging problem-solving environment (Akerson & Dickinson, 2003; Baker & White, 2003; Carlson, 2007; Kerski, 2007; NRC, 2006; Stubbs et al., 2007). In fact, many educators have been successful with using GIS in K-12 classrooms (Alibrandi, 2003; Barnett, Houle, & Strauss, 2008; Bodzin, 2008; DeMers & Vincent, 2007; Doering & Veletsianos, 2007). The complexity of the technology, however, has hindered widespread acceptance and only a limited number of students have access to the technology (NRC, 2006). Researchers and practitioners have found that existing GIS software packages (such as *ArcView*) are very difficult to use as general educational tools for the K-12 context. In particular, the National Research Council (2006) noted that the practical problem of adapting GIS in its current desktop-based form to the K-12 environment is immense. As argued by the NRC, current GIS technologies are expert-based, "industrial strength" technologies that are inviting because of the potential for engaging students in authentic science yet are difficult to learn and challenging to install and manage in most school computer laboratories. Through the implementation of our program, we have found this to be all too true; however, we have also found that an immersive professional development program appears to offer great promise in helping to improve teachers' ability to use and implement geospatial technologies. To that end we now believe that professional development programs that focus on the use of geospatial technologies should have:

1. Scaffolding of the curriculum to anticipate what might go wrong with the technology and troubleshooting hints and strategies to assist with potential technological problems and provide teachers experience in solving these problems within the professional development experience.
2. To learn how to use GIS, in particular, a professional development needs to be immersive and not just a series of workshops.
3. A learning trajectory that starts teachers at lower level, introductory geospatial technologies such as Google Earth and supports their progress toward more sophisticated geospatial tools such as CityGreen.
4. Opportunities for teachers to work with students to conduct geospatial analyses as this appears to be critical to enhance teachers' self-confidence and ability to conduct scientific-inquiry investigations. However, there needs to be a balance for teachers for opportunity to reflect, revise, and learn from the experience with students during a program like ours.

We have found the design and implementation of our program challenging, rewarding, and enlightening in regard to how to support teachers in implementing cutting edge technologies to teach students scientific concepts. We hope that our growing pains, the lessons learned along the way, and the work of others in this volume provide some insight regarding how we can develop effective programs to support teachers in using geospatial technologies in the coming years.

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