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Urban environmental education: leveraging technology and ecology to engage students in studying the environment

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In this paper, we describe the outcomes of the first year of an intensive, urban ecology focused, summer program for urban high school youth. Students in our program conduct scientific investigations of their urban ecosystems while exploring potential career options in science and technology fields. In conducting their investigations, the students used geographic information systems (GIS) coupled with computer modeling tools and visualization software to explore the ecological services provided by their urban forest canopy and the impact of urban noise upon birdsong. The goal of the program was to improve students' self-efficacy toward science and their sense of environmental stewardship. To that end, we conducted pre–post surveys of students on their beliefs regarding their (1) science self-efficacy, (2) science interest, (3) environmental stewardship and (4) career knowledge and career awareness. In this paper, we focus our discussion on the first three outcomes and found that participation in our program significantly improved students' science self-efficacy and environmental stewardship. We found that by engaging students in locally, focused, in-depth and targeted environmental science investigations, students could develop the confidence to investigate and solve local problems that increased their confidence in their ability to do and study science.

Keywords: urban environmental education; geographic information systems (GIS); urban ecology

Introduction

Urbanization trends of the past century show a dramatic rise in the size of cities worldwide. More than 300 cities have more than 1 million inhabitants, and 16 "megacities" have populations exceeding 10 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 healthy and sustainable are the young people who live in cities. Unfortunately, all too often, students are unaware of the importance of the urban ecosystem in which they live. Further, students often lack the necessary scientific skills to understand how their actions impact local urban ecosystems, how they can improve and change their

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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 many high school classrooms has focused on a traditional view of the study of ecology by focusing their learning efforts on 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.

Paralleling the growing recognition of the importance of urban ecosystems environmental education, there is a growing use of advanced visualization technologies within the field of environmental science. For example, data visualization technologies such as Geographic Information Systems (GIS) and sound visualization technologies have emerged over the last 15 years as one of the key 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. Unfortunately, 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, 2006); however, recently, there has been a dramatic increase in the availability of relatively user friendly geospatial and visualization technologies, such as *MyWorld*, *Google Earth*, *Raven* and access to scientific data for educators. The availability of these programs at low costs has increased the potential for integrating visualization technologies in environmental science education programs.

With the goal of improving students' understanding and appreciation of their local urban ecosystems, we have been implementing an out-of-school time, technology-rich, urban ecology education program designed to improve students' sense of ecological stewardship, interest toward science and science self-efficacy, while supporting students in exploring potential careers in science-oriented domains. In this paper, we report on the outcomes of the first year of our work.

Conceptual frameworks

Pedagogical praxis and participatory authentic learning

The model that we have used for integrating our program into our program has been jointly informed by Shaffer's theory of pedagogical praxis (Shaffer, 2004) and a participatory learning environment framework as described by Barab, Hay, Barnett, and Keating (2000). 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 visualization tools by laypersons to explore the natural world. For example, *Google Earth* and *Google Maps*, two of the most well-known geospatial technologies, have not just enabled 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.

In the field of urban ecology, new technologies have enabled rapid development of our understanding of how urban ecosystems change and evolve over time. In order to understand an urban ecosystem, urban ecologists need to evaluate the biological and geophysical components of the system and determine how those components are linked to the socioeconomic aspects of human life. That is, given their holistic paradigm, urban ecologists tend to take a central role in trying to keep urban systems sustainable through understanding the deep interconnectedness between humans and the natural environment, and emerging visualization technologies have been critical to that effort (Alberti, 2008). When students are immersed in learning experiences that incorporate these technologies, they develop competence in the scientific practices involved in urban ecology and pass these educational benefits on to their students (Barnett, JTATE cite).

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 readymade 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 working in isolation (Resnick, 1987); (4) learners should not be 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 the 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 and not simply hearing about the work of other authentic science communities.

In our project, we have been striving to engage students in becoming – or at least engaging in the practices of – urban ecologists through the evaluation of the ecological, economic and social benefits of green space for urban residents and understanding the impact of the built environment on the natural ecosystem. To do this, our program has been constructed around the typical practices of professional urban ecologists and urban planners. This latter point is particularly critical because according to both pedagogical praxis and participatory learning, successful learning environments depend upon the alignment of authentic professional practice and the practices undertaken by the learners (Beckett & Shaffer, 2005).

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). 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. Drawing upon the tools of the social, physical and natural sciences, urban ecologists seek to understand the impact of the human-built system on the environment and how anthropogenic and natural forces and drivers interact to shape urban ecosystems. 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). Using urban ecology as a framework involves students directly in data collection and engages them as active participants in improving their neighborhoods (Barnett, Houle, & Strauss, 2008; Barnett et al., 2006). Further, by focusing on local environmental issues, students are more likely to connect their local knowledge to larger regional and global environmental issues (Ruiz-Mallen, Barraza, Bodenhorn, & Reyes-Garcia, 2009) and they are more likely to develop a deeper understanding of the scientific, cultural and historical value of the place in which they live (Planinc, 2008).

Educational technology: use of visualization and geospatial technologies

Historically, scientists and educators have used computational and visualization technologies to investigate and explore complex systems and phenomena. During the last decade, the tools that practicing scientists use to build computational models intended to visualize complex concepts and phenomena have been harnessed to help students learn science (Edelson, Gordin, & Pea, 1999; NSF Task Force on Cyberlearning, 2008). This is due, in part, because educators have recognized that visualizing data can facilitate the development of mathematical–scientific understanding of the natural world (Kim, Hannafin, & Bryan, 2007). Further, the growing power of computers, coupled with a reduction in cost and the availability of inexpensive or free computational software, has created opportunities to engage students in scientific inquiry through visualization and simulation of scientific phenomena (Vogel et al., 2006).

Much of our work has focused on how to leverage Geospatial technology as an educational tool, in particular GIS. GIS is a specific type of geospatial technology that is rapidly emerging as a powerful tool for use in science classrooms (Barnett, MaKinster, Trautmann, Houle, & Mark, in press). Educational use of GIS-based tools began in geography but has extended into science, with an ever-growing assortment of online resources, publications and professional development opportunities for teachers. Educators have found that the use of geospatial technology can create meaningful contexts for learning (Lee & Bednarz, 2009; Teo, Lee, Chai, & Wong, 2009), which can provide students with opportunities to address real-world issues and through that exploration, students can make connections between disciplines. For example, what may first appear to be a scientific question may actually draw upon social science data and add a political and economic context to the problem being addressed. The use of geospatial technology also enables students to integrate scientific, social, economic and political perspectives underlying scientific problems and issues. The ability to integrate these perspectives often enables students to develop recommendations for potential solutions that reflect real-world complexity (National Research Council, 2006).

Visualization technologies and environmental science education

Accompanying the rapid growth in development and use of geospatial technologies is an increase in knowledge regarding how to support and engage students in doing science (Bransford, Brown, & Cocking, 1999). In the recent document, *Taking Science to School* (National Research Council, 2007) strongly argued that in the doing of science, the process of doing science and the content of science are deeply interconnected. This relationship between process and content is central to the educational research and application of geospatial technologies (Lee, Quinn, & Duke, 2006; National Council for Geographic Education, 2006; NSF Task Force on Cyberlearning, 2008; Wang, 2008). In fact, geospatial and environmental educators have begun to recognize that the pedagogical power of geospatial and visualization technologies supports the arguments put forth in *Taking Science to School* regarding how to best engage students in scientific inquiry (McInerney, 2006). For example, using geospatial technologies in environmental education facilitates the process of scientific problem-solving through the exploration of real-world contexts and projects, providing students with opportunities to see the utility of such technologies in all phases of the scientific process. This is consistent with assertions by many scholars that if students are to develop rich, meaningful and useable understandings of scientific phenomena, as well as the process of scientific knowledge construction, they need to be engaged in a scientific community of practice in which they are doing science in real-world settings with tools similar to those being used by scientists and other professionals (Barab et al., 2000; Lave & Wenger, 1991).

Building on these perspectives, geospatial technologies have significant potential to engage students in locally relevant, interdisciplinary study of phenomena with direct impact in their daily lives (Barnett et al., 2006). For example, students can use geospatial technologies not only to map data and explore digital representations of Earth's surface but also to visually explore relationships between various types of environmental and social data. By overlaying different data layers, students can identify areas of environmental concern in their own communities, such as steep slopes vulnerable to erosion, or areas of greatest benefit, such as habitat for a threatened or endangered species. Students also can examine relationships between biological and social variables. For example, in urban areas, they might consider comparing the health of trees, shrubs and other vegetation with neighborhood income levels. Such relationships can be explored not only visually but also by using the analytic capabilities of a GIS. In essence, these technologies provide an ideal tool for students to use when visualizing data, posing their investigation and addressing specific questions. These process skills are critically important as being able to visualize and manipulate data can increase students' ability to transfer new knowledge to novel situations (Bransford et al., 1999) and can help students understand complex science concepts and phenomena (Gordin & Pea, 1998).

Visualization technologies and environmental education

Place-based education has become a commonly used framework for thinking about teaching and learning in environmental education as it appears that understanding history and context of place can support the development of environmental stewardship of a place (e.g. Smith, Edwards, & Raschke, 2006). The use of visualization technologies coupled with the study of urban ecological concepts affords students with an interdisciplinary approach to science that combines the power of science, *as a way of knowing*, with the direct impact of active learning, and being of service within the local community (Berkowitz et al., 2003). The ability to critically examine a specific place or location from a range of perspectives using geospatial technologies enables students to ask and answer many questions regarding their community such as "How is land used in my area?", "How many supermarkets are within walking distance?", "Are there specific areas in my neighborhood where ozone concentrations are particularly high?" or "Where is air pollution the worst, and is there a relationship between these locations and the amount of vegetation?". In the past, a significant amount of time was required for students to explore and answer each of these questions. With today's technologies, however, each question can be quickly explored and/or answered, allowing students to investigate deeper and more challenging questions regarding the historical, economic, social and scientific underpinnings of the nature and structure of the area in which they live.

Study context

Urban ecology institute summer program

Our complete summer program consists of four weeks of instructional time. The first two weeks focus on improving teachers understanding of visualization and geospatial technologies and the science of urban ecology. During the first year, we had 30 teachers who participated in the program. The teachers were primarily high school teachers who taught biology and the occasional environmental science class. The first week of the teacher institute focused on the foundations and the science of urban ecology. Whereas during the second week, teachers chose to focus on a particular project: (1) bioacoustics or (2) urban street trees (see descriptions below and view a video of the implementation of a project in a classroom at http://itestlrc.edc.org/inside_itest/maprofile.html). However, the focus of this paper is on the second 2 weeks of the institute during which we brought 61 urban high school students to campus to learn about bioacoustics and urban street trees. Teachers who continued in the program were asked to lead a group of four to five students in the same project content they studied in Week two of the institute. For the purposes of this paper, we will focus on the impact of the program on student outcomes (for impact on teachers see Barnett et al., in press).

Projects: understanding urban ecosystems through technology

Project No. 1: bioacoustics

This project was sparked by recent bioacoustics research and challenges students to explore how urban birds adapt their communication systems to deal with urban noise. In 2003, a landmark study published in *Nature* found that small songbirds (*Parus major*) breeding within the Dutch city of Lieden 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 environment 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 mechanistic 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 Figure 1). RAVENlite allows students to quickly view and visualize their data, evaluate their recordings and explore how urban noise in their city impacts birdsong, comparing those data with existing birdsong recordings. Following this analysis, the students generate research questions, conduct additional research and present their findings to others.

Project No. 2: urban street trees

The urban 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 develop by American Forests that plugs into the Geographical Information Systems software package, ArcView. CITYgreen allows students, through the use and labeling of satellite images, to link each tree location to a database of geographic, classification and health information and to conduct analyses regarding the economic and ecological benefits of urban trees (see http://www.americanforests.org/productsandpubs/citygreen/for a description of CITYgreen).

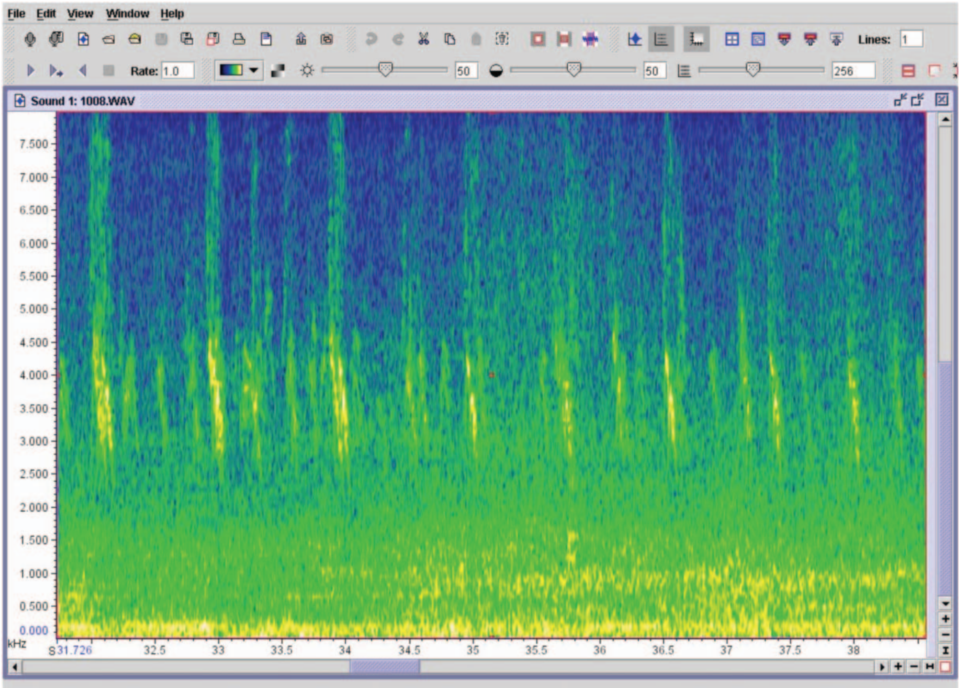


Figure 1. Student recording of birdsong and ambient noise as seen in RAVENlite. The vertical lines represent chickadee song and the bottom portion of the image represents background noise.

Students collect data on tree location and condition and use CITYgreen to evaluate the economic value of street trees on such constructs as storm water runoff, energy savings and air pollution removal (Barnett et al., 2010; Barnett et al., in press). 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 their neighborhood) 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" where the city has diverted the major interstates that were running through city into underground tunnels and 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 and evaluate their data (see Figure 2 for a screen shot of CITYgreen and Figure 3 for a report). This latter investigation is possible because CITYgreen allows students to model a tree growth over time that enables them to evaluate what their urban street canopy will look like in 10 years (see Figure 4).

Data collection

A mixed methodological strategy was used for data collection in this research (Tashakkori & Teddlie, 1998). At the start of the two-week student portion of the institute, the students were asked to complete a survey that contained multiple scales: (1) science self-efficacy, (2) science interest, (3) ecological mindset, (4) career planning and (5) work hope. The

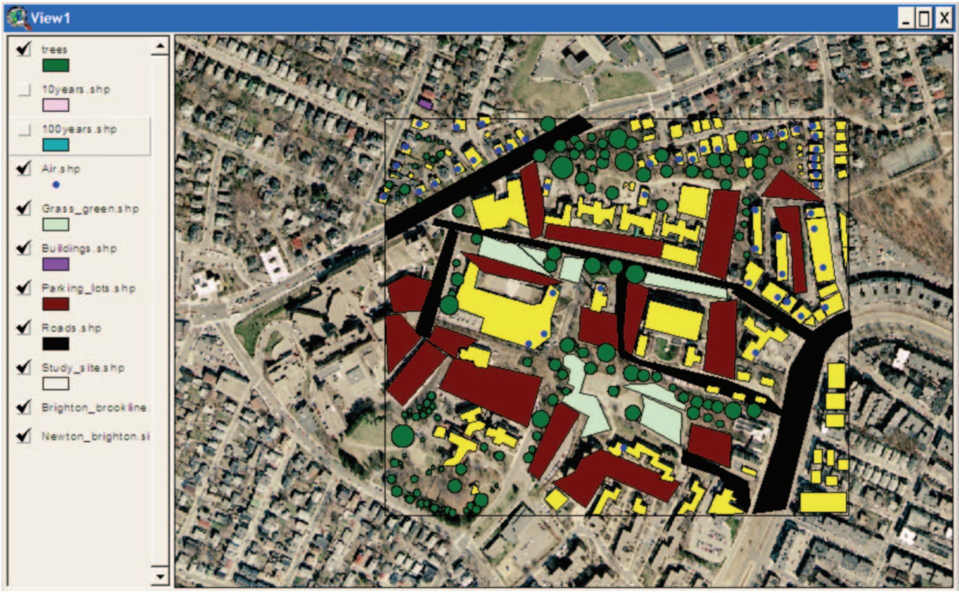


Figure 2. CITYgreen image and report regarding the impact of street on energy savings, air quality and storm water runoff around a Boston public high school.

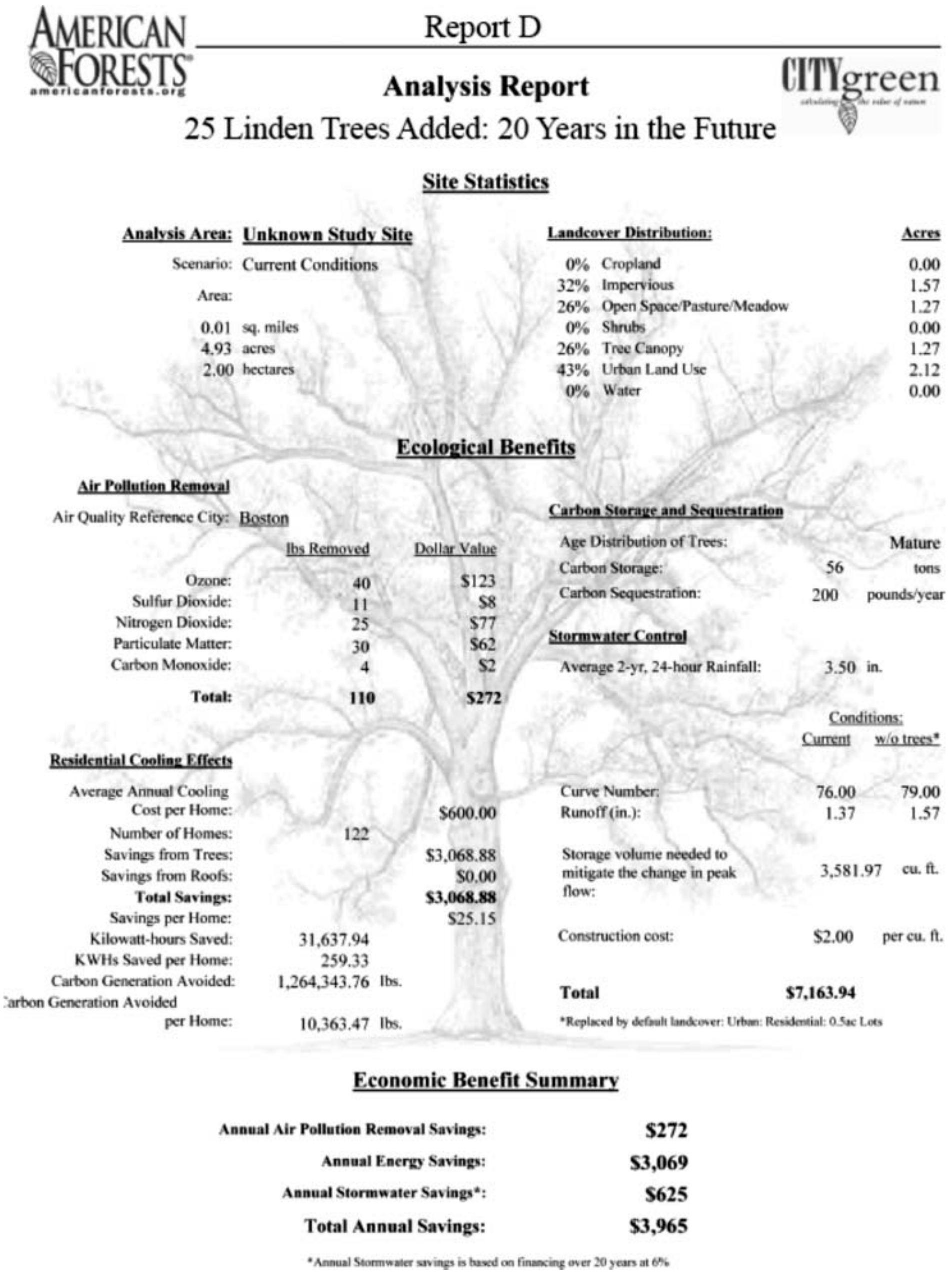
instruments have been posted at our project website at http://urbanecologyscience.org. All but two of the students (arrived late and missed the survey administration) completed both the pre–post survey. In addition to the quantitative data, the students were asked to complete open-ended response items. There was a researcher present in both the bioacoustics and urban street tree project as a participant observer with the goal of noting where students were struggling in terms of content, learning the technology, their career aspirations and their general perceptions of the institute. Unfortunately, given tight time constraints of the summer program, it was difficult to conduct a traditional pre–post interview with the students which limits our ability to describe at a more qualitative and in-depth level of how participation in the institute impacted individual student beliefs and the nuances of those beliefs may have changed over the course of the institute.

Student population

There were a total of 61 students who attended the summer institute with 59 completing the survey as noted previously. The students were chosen to attend the summer institute through a competitive selection process from inner city high and middle schools in the Boston area (see Table 1 for detailed demographics of the student population).

Table 1. Student demographics.

Project	Number	Race	Number
Bioacoustics	32	African-American	30
Tree	29	Asian-American	7
		White	1
		Latino/Latina	6
Girls	31	Native	0
Boys	30	Other	5



AMERICAN FORESTS
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Report D

Analysis Report

CITYgreen

25 Linden Trees Added: 20 Years in the Future

Site Statistics

Analysis Area: Unknown Study Site

Scenario: Current Conditions

Area:

0.01	sq. miles
4.93	acres
2.00	hectares

Landcover Distribution:		Acres
0%	Cropland	0.00
32%	Impervious	1.57
26%	Open Space/Pasture/Meadow	1.27
0%	Shrubs	0.00
26%	Tree Canopy	1.27
43%	Urban Land Use	2.12
0%	Water	0.00

Ecological Benefits

Air Pollution Removal

Air Quality Reference City: Boston

	lbs Removed	Dollar Value
Ozone:	40	$123
Sulfur Dioxide:	11	$8
Nitrogen Dioxide:	25	$77
Particulate Matter:	30	$62
Carbon Monoxide:	4	$2
Total:	**110**	**$272**

Residential Cooling Effects

Average Annual Cooling Cost per Home:		$600.00
Number of Homes:	122	
Savings from Trees:		$3,068.88
Savings from Roofs:		$0.00
Total Savings:		**$3,068.88**
Savings per Home:		$25.15
Kilowatt-hours Saved:	31,637.94	
KWHs Saved per Home:	259.33	
Carbon Generation Avoided:	1,264,343.76 lbs.	
Carbon Generation Avoided per Home:	10,363.47 lbs.	

Carbon Storage and Sequestration

Age Distribution of Trees:		Mature
Carbon Storage:	56	tons
Carbon Sequestration:	200	pounds/year

Stormwater Control

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

	Conditions: Current	w/o trees*
Curve Number:	76.00	79.00
Runoff (in.):	1.37	1.57

Storage volume needed to mitigate the change in peak flow:	3,581.97	cu. ft.
Construction cost:	$2.00	per cu. ft.
Total	**$7,163.94**	

*Replaced by default landcover: Urban: Residential: 0.5ac Lots

Economic Benefit Summary

Annual Air Pollution Removal Savings:	**$272**
Annual Energy Savings:	**$3,069**
Annual Stormwater Savings*:	**$625**
Total Annual Savings:	**$3,965**

*Annual Stormwater savings is based on financing over 20 years at 6%

Figure 3. CITYgreen report showing air quality, energy savings, carbon sequestration and storm water runoff savings.

Our selection process focused on recruiting students who were considered by their teachers to be "C" or average students with a special emphasis on recruiting students whom their teachers felt would benefit from studying science outside of a traditional school setting.

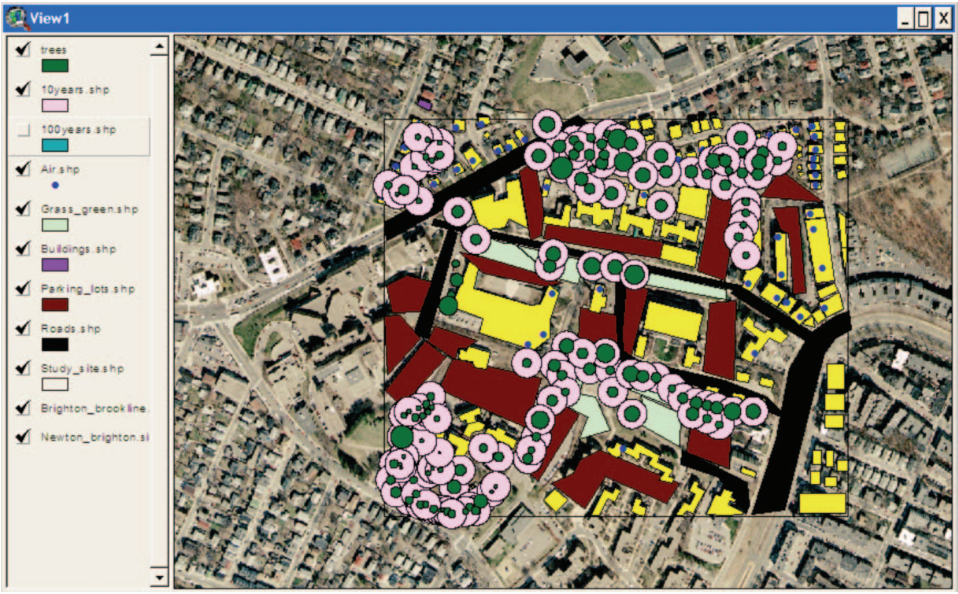

Figure 4. CITYgreen image and report regarding the impact of street on energy savings, air quality and storm water runoff after 10 years. Note that the smaller interior circles represent the size of the trees as they are now and the larger circles represent the size of the trees 10 years into the future.

Data analysis

The survey data were analyzed using paired t-tests and analysis of covariance (ANCOVA) to evaluate whether gender or race had any impact on the results. Upon conducting a reliability analysis, we found that all the scales on the student survey had high reliability (see Table 2 for reliability results for student scales). We then conducted paired t-tests to evaluate how participation in the summer institute impacted student outcomes. Following this analysis, we conducted ANCOVAs to evaluate whether there were any additional interactions in the data. To analyze the qualitative data, we read through the student open-ended items with a critical eye toward looking for confirming or disconfirming evidence that either supported or refuted our quantitative findings.

Results and discussion

Quantitative results

We found that students' self-efficacy toward science showed a significant change from the beginning to the end of the summer institute ($M_{pre} = 3.00$, $M_{post} = 3.80$, $t = 8.58$, $p < .01$) and students' ecological mindset showed a significant increase ($M_{pre} = 3.39$,

Table 2. Student survey reliability.

Number	Scale name	Reliability (α)
1	Science self-efficacy (1)	0.90
2	Science interest (2)	0.87
3	Ecological mindset	0.80
4	Career planning (3)	0.91
5	Career knowledge (4)	0.90

$M_{post} = 3.71$, $t = 3.71$, $p < .01$). We did find that science interest improved slightly from $M_{pre} = 1.4$ to $M_{post} = 1.5$; however, the change was not significant ($t = 0.58$, $p < .55$). The lack of a significant change in science interest is not surprising because students who attended the program entered the program with a strong interest in science or else they would not have applied to attend the summer institute. However, given that we were able to increase their science interest to any degree, we found to be a positive outcome of program participation. We also found that students' career planning ($M_{pre} = 2.59$, $M_{post} = 3.01$, $t = 1.51$, $p < .01$) and work hope ($M_{pre} = 2.59$, $M_{post} = 3.04$, $t = 1.54$, $p < .01$) perceptions did improve, but they did not improve at a statistically significant level. The research base on career development does suggest that for students' beliefs regarding their career goals and objectives, an intervention needs to occur and be sustained over time (Blustein & Flum, 1999). However, given that our results did reveal an increase in student career perceptions, we believe that short-term summer programs can serve as an important component of any environmental education program.

We found that there was no difference between gender and race on any of the three scales. This finding is significant because researchers have found that male students in high school and college tend to be more confident than female students in academic areas related to mathematics, science and technology (Parajes & Schunk, 2001). Therefore, participation in our summer institute appears to improve both male and female self-efficacy. In terms of race, our findings are interesting because researchers have found that science self-efficacy can serve as a predictor of science achievement for African-American students (Britner & Parajes, 2001). Thus, our findings suggest that the students who participate in our program may perform better in their science courses later. As of this writing, we are currently in the process of tracking students' grades and enrollment patterns over time and are unable to report on any correlations at this time. Lastly, the significant change in science self-efficacy was a bit surprising because science self-efficacy, which is the confidence that one has in one's ability to complete a scientific task, is often a characteristic that requires time to develop and change (National Research Council, 2004).

In terms of ecological mindset, which we define as students' sense of environmental stewardship, we found that all student groups showed significant improvement which is important because the research literature reveals that young people are generally pessimistic about the future and generally feel powerless to do very much about environmental problems (Connell, Fien, Lee, Sykes, & Yencken, 1999). This finding is also surprising in that older students tend to show very little growth in their environmental attitudes from short-term interventions (Yount & Horton, 1992). Our findings support Manzanal et al.'s (1999) results in which they found that when ecological field experiences are focused on a small subset of environmental topics, students show improvement in their affective attitudes toward the environment. In addition, Manzanal et al. argue that if ecological field experiences are too general, students often become overwhelmed by the richness and the complexity of the ecosystem that inhibits students' ability to understand and solve environmental problems. Thus, by focusing our students' scientific research on specific environmental science topics such as urban forests and bioacoustics, we helped to focus students' interests and not overwhelm them by asking them to learn and integrate too many abstract scientific concepts at one time.

Qualitative results

From an analysis of the student open-ended responses and their summative evaluation feedback on the program, we found that students' who participated in the summer program felt that they (1) developed a sense of completion and pride in their work and improved self-efficacy and (2) developed a better sense of the value and the challenges that their urban environment faces. We explore each of these themes in the following sections.

Sense of pride/completion

It has been well documented in the urban education literature that students often perceive themselves engulfed in the cycle of failure (National Research Council, 2004). For instance, many urban students tend to believe that they will not succeed regardless of how much they work and as a result tend not to complete or accomplish school-related tasks. This cycle then leads students to believe that they are unable to complete more complex tasks because they are either perceived to be too difficult or irrelevant to their lives. However, it appears that the design of our summer program supported students in engaging in and completing specific, yet rather complex tasks. In completing their work, this was the first time that many of the students felt that they could complete and understand scientific concepts. This sense of pride of completion is expressed in the following student statement who participated in the urban tree project:

> The project was hard and it wasn't my first choice of projects because I've never been good with computers but our team got this done and I learned a lot about urban trees and GIS. I'm looking forward to coming back next year to learn more!

This sense of accomplishment was also expressed on the final summative feedback assessments from the students as illustrated by the following comments:

> I learned a lot and I never had to talk in front of someone else before. I was very happy with our project and learned a lot about computers and trees. I had never finished a project in school before and did this one. I'm looking forward to next year.

> I learned that I could complete a science project from beginning to end.

> I learned that it is not that hard to learn how to use technology to answer a question.

We speculate that the sense of accomplishment by the students was a primary factor in their improved science self-efficacy. This claim is based on the fact that researchers who have examined the development of self-efficacy have found that students who are encouraged and told that they have the ability to master new or difficult science tasks are more likely to persevere which in turns promote the development of high science self-efficacy (Britner & Parajes, 2001).

Improving and impacting the urban environment

There has been little research that has focused on urban students perceptions of their urban environment and students' beliefs around how to improve their urban environment. However, the research been done is that students in urban areas tend not to believe that cities are viable ecosystems nor do they believe that there is a lot that they can do to improve their environment (Worsley & Skrzypiec, 1998). This belief was expressed early in the summer program on the student formative feedback documents as illustrated by the following two student statements:

> I would like to think that we can make a difference, but to be honest I really doubt it. There are so many people who don't care and they make a big impact on the environment.

> The environment is all the things around you like trees, grass, open space, flowers, anything that is growing, green, and alive. Unfortunately, I don't think many people even notice it when they are in a city. They just see pavement and buildings and not all the living things around them.

At the conclusion of the summer institute, we found that students did shift their ideas regarding the environment and how they impact their environment as illustrated by the following two statements:

> I have enhanced my research skills & I have learned how to help my environment. I also obtained a very clarified understanding on how we unconsciously injure our environment.

> I had not thought of Boston as the environment in the way that Dr Strauss presented. I had always thought of the environment as something with lots of open space and not a city.

Implications for environmental education

Within the field of environmental education, summer programs that engage students in exploring the environment are quite popular; however, a review of the research base finds very little research on the impact of such programs on student affective outcomes. Although our results are from a limited sample both in terms of time and number of students impacted, our findings do suggest that summer programs have a great deal of promise in improving students' science self-efficacy, ecological mindset and appreciation for their urban ecosystem. The improvement in science self-efficacy is particularly important because educational researchers have found that urban students and students of color have exceptionally high negative attitudes toward school science and their futures in that field (Atwater, Wiggins, & Gardner, 1995), many urban students and students of color do not feel that they can do science (Buxton, 2005) and science as taught in schools is irrelevant and disconnected from their daily lives (Nieto, 1994). Further, our findings suggest that engagement in urban ecological scientific problems not only improves students' ecological mindset but also their science self-efficacy. This finding is particularly salient when one considers Bandura's (1986) argument that students' self-efficacy beliefs are often better predictors of the academic successes that students attain than are objective assessments of their abilities. This is because students' efficacy beliefs mediate the effects of prior achievement, knowledge and skills on subsequent achievement. Finally, this study contributes to the environmental education research literature because very few research studies have examined environmental attitudes and whether participation in environmental science education programs impact African-American student affective outcomes.

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