# Improving Urban Youth's Interest and Engagement through Field-based Scientific Investigations

Michael Barnett[1], Eric Strauss[2,4], Camelia Rosca[1], Heather Langford[3], Dawn Chavez[5], Leah Deni[5], Charles Lord[4,2]
[1] Lynch School of Education, Boston College, Campion Hall Room 123, Chestnut Hill, MA 02453
Tel: 617-552-0658, Fax: 617-552-1840
E-mail: barnetge@bc.edu
[2]Biology Department and Environmental Studies Program, Boston College, strausse@bc.edu
[3]Casey Trees Endowment Fund, Washington, DC
[4]Urban Ecology Institute, Chestnut Hill, MA

**Abstract:** Equity is at the heart of the current efforts to reform science education. Recent reform documents explicitly put forward the idea that all students regardless of culture, gender, race, and/or socioeconomic status, are capable of understanding and doing science. Despite this emphasis, there continue to be widespread differences in the access, retention, and achievement of students depending on their culture, gender, race, and/or socioeconomic status. To address this need, the Urban Ecology Institute in partnership with the Boston Public Schools and the Lynch School of Education at Boston College has been developing and implementing a field-based science program to engage traditionally underrepresented groups in the doing of real-world science. To date we have found that our program improves student interest in science, supports students in developing a better understanding of scientific methodologies, and improves students' sense of environmental stewardship when compared to students experiencing traditional science instruction over the course of an academic year.

## Introduction and Purpose

Recent reform documents explicitly put forward the idea that all students regardless of culture, gender, race, and/or socioeconomic status, are capable of understanding and doing science (National Research Council, 1996). Despite this emphasis, there continue to be widespread differences in the access, retention, and achievement of students depending on their culture, gender, race, and/or socioeconomic status (Hewson, Kahle, Scantlebury, & Davies, 2001). For the past decade, educators, researchers, and policy makers have been examining ways to engage all students in the doing of science (Knapp, 1997). Unfortunately, many efforts have met with little societal success as documented by recent National Science Foundation figures that show the numbers and percents of African-Americans, Hispanics, and American Indians lag behind Asian-Americans and Americans of European origin in Science, Technology, Engineering, and Mathematics careers (National Science Foundation, 2002). For example, findings from a 1999 National Science Foundation report show that only 7% of all positions in science and engineering were held by minorities despite constituting 24% of the current United States population (National Science Foundation, 2002). This state of affairs has led some researchers to question whether the education community's commitment to equity and diversity is a pious platitude or an achievable goal (Hewson et al., 2001).

There is a growing recognition that one constituent of the science education reform process must be a sustained effort toward making the study of science accessible to more students (Jones, 1997). Also, given the under-representation of minorities and women in scientifically-based fields it is important to examine ways that such populations can be engaged and encouraged to study science (NSF, 2002). To this end, a partnership was formed between the Urban Ecology Institute, the Boston Public Schools' Science Department, local community centers, and a university-based school of education to implement and develop an Urban Ecology Field-Based Studies Program (UEFSP). The goal of the partnership is to improve student interest toward science and understanding of the scientific process by using their local environment as a laboratory. In service to these goals, our research agenda has been focused on investigating the following questions:

1) Does participation in our program improve students' interest and self-confidence in science?

1) Does participation in the program foster students' sense of environmental stewardship and civic responsibility?
1) What aspects of the Urban Ecology Field Studies Program improve student interest and engagement in science?

## Background

Students often report that what they learn lacks relevance to their lives and where they live (Nieto, 1994). This is particularly evident in school science, which typically reflects an European-oriented perspective and excludes the lives of students on the margins of science such as African-Americans and other minorities (Atwater, 1996). To address this gap, many educators have been examining and researching how to design experiences that motivate and excite students from traditionally underrepresented populations in science (Fusco, 2001; Jones, 1997). At the forefront of this movement are educators who are exploring out-of-school science experiences. These experiences appear to be fruitful because learning outside of school engages activities situated in real-world cultural contexts (Fusco, 2001). In addition, these outside experiences have also been found by young people to be the most "fun" and relevant to their futures (National Science Foundation, 1998).

In terms of environmental education, researchers have been examining how field-based experiences impact one's perspectives toward the natural world. Nearly all studies have focused on understanding how adult learners' attitude toward the environment changes as a result of participation in a particular program (e.g. Palmer, Suggate, Robottom, & Hart, 1999). These studies have provided data regarding the perceptions of the general adult population, but provide little insight regarding how such experiences impact youth (Gough, 2001; Loughland, Reid, Walker, & Petocz, 2003). Thus, little work has been done examining the impact of field-based scientific experiences on youth's understanding of scientific methodology, whether such programs impact their beliefs regarding environmental stewardship, their perceptions of science, and their interest in science (Hudson, 2001). However, recently, urban science education researchers have begun examining how science learning unfolds in informal, outdoor experiences. For example, Hogan (2002) examined students ecological reasoning as they engaged in an environmental management decision process, Fusco (2001) and Rahm (2002) found that urban students learning of content and process improved over time as they participated in community-based urban gardening programs.

Paralleling this work in urban science education is the re-emergence of designing educational experiences for students that connect traditional academic learning with service to the local community (Moore & Sandholtz, 1999). A primary advantage of using such an approach to engage students is that it directly involves students in collecting data and engaging them as active participants in improving their neighborhoods (Carter, 1997). Students participating in the UEFSP collect, analyze, and report on data that are directly relevant to their local neighborhood. The students' data and results are then used by scientists and policy makers to better understand how to improve the students' neighborhood ecosystem. In this paper, we compare the impact on student attitude, sense of stewardship, and understanding of scientific methodologies after participating in the UEFSP with control groups.

### Description of the Urban Ecology Field Studies Program

The UEFSP engages students in urban public schools in the scientific process by combining the immediate relevancy of urban backyards with basic scientific research. Built upon the educational process of inquiry, each study is framed around the question: What is the health of Boston's urban ecosystem? Using this overarching question as the context, the UEFSP consists of four types of studies (1) introduction to field studies, (2) mapping, (3) water quality monitoring, (4) biodiversity. To date, teachers use the curriculum materials to augment their environmental science, earth science, biology, chemistry, physics, marine science and special education services and supports. In short, the UEFSP provides multi-sensory opportunities for students to learn about collecting, analyzing and presenting scientific data.

#### Scientific Foundations

The primary thrust of our work is drawn from the emerging field of 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 p. 33). In short, urban ecology is a subject around which inquiry-based science activities can be built by critically examining the science standards and constructing scientific experiences that address both the content and the inquiry processes described in the standards (Bybee, 2003). Thus, urban ecology affords a thoroughly 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 curriculum around urban ecology constructs, students are immersed in a locally relevant and inquiry-oriented learning environment. In short, this curricular strategy emphasizes both process and content, moving away from the "survey of the sciences" 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).

## Pedagogical and Theoretical Framework

The guiding developmental framework for our curriculum is based on the concept of backward design (Krajcik, 2003; Singer, Marx, Krajcik, & Chambers, 2000). That is, we first begin with the science standards to determine what it is that students need to know, and then develop contextualized and locally relevant instructional materials based upon the need. Embedded within this framework are our design principles which are based upon a combination of authentic pedagogy (Newmann, Marks, & Gamoran, 1995), social constructivism (Singer et al., 2000), and Universal Design for Learning (Rose & Meyer, 2002). Our guiding principles are: (1) Construction and demonstration of knowledge, (2) Disciplined scientific inquiry, (3) Use of learning technologies, (4) Value beyond school, and (4) Flexibility in materials and tools. In short, our curriculum materials are designed to engage students in reflecting on and critically examining their prior conceptions and then through inquiry-oriented investigations students learn content, learn about their place in the environment, and develop skills that that serve them outside of the classroom.

The UEFSP engages students in the scientific process by combining the immediate relevancy of their own urban ecosystem with basic scientific research. Built upon the educational process of inquiry, each study is framed around the question: What Is the Health of Boston's Urban Ecosystem? This synthesis of science, education, and urban ecosystems is designed to: (1) increase students' intellectual and social self-confidence, (2) familiarize students with the scientific method, and (3) foster environmental stewardship and civic responsibility. In the process, the program helps young people to develop specific skills including the ability to perform open-ended investigations, mastery of the scientific method, the ability to create and interpret graphs, an understanding of basic ecological principles, and practice in public speaking. In order to meet these goals, the Urban Ecology Field Studies Program provides professional development opportunities, materials, curriculum, and on-going support for teachers.

## Major Program Components

The basic elements to the UEFSP's framework are: Professional Development, Curriculum Enhancement Materials, Classroom Preparation, Field Research, Classroom Applications, and an Annual Student Research Conference. A week-long Summer Institute is offered each July for teachers, community leaders, and urban professionals to define a common forum for initiating community-based, urban research. Before students' first field visit, they are provided background on urban ecology and how to conduct field work. They are instructed on use and care of the field equipment, safety precautions, teamwork, and how to dress appropriately. Each school's study field site is located in close proximity to the school, ideally within walking distance but with some sites requiring a short bus ride. At present, teachers can choose from a variety of studies, including: water quality monitoring, avian diversity, coyote, crow, and turtle ecology and behavior studies using radio telemetry. The experiments are supported by standards-based curriculum materials designed to integrate into the teachers' existing curriculum. The culminating event of the program occurs at the end of each school year when participating students present the outcomes of their investigations at a local university in the form of a scientific conference. To aid teachers in the implementation of these program components, the Urban Ecology Institute provides trained Field Assistants (AmeriCorps*VISTA Volunteers and university undergraduate and graduate students) as well as small grants for equipment and transportation costs. The Field Assistants serve as liaisons between the schools and the Urban Ecology Institute, and are available for field and classroom assistance including directly working with students and consulting with teachers to prepare classroom and field lessons. When needed, Field Assistants also provide logistical support to the teachers to order equipment and arrange transportation.

### Field-Based Research

The Urban Ecology Institute currently provides support for a variety of studies, including: water quality monitoring, avian diversity, and coyote, crow, and turtle ecology and behavior studies using radio-telemetry. Additional studies are being developed, often specialized for a particular study site or a teacher's interest. All of the educators in the program are strongly encouraged to link their field research to the local community through UEI's Social Ecology studies. The field site is selected by the teacher in conjunction with the Urban Ecology Institute and local watershed associations and environmental agencies. Each school's study site is located in close proximity to the school, ideally in walking distance but with some sites requiring a short bus ride. The same sites are used each year in order to provide long-term, comparative data. By using the same site for several seasons, teachers can probe for seasonal variations and explanations. These exercises help students prepare for standardized assessments that deal with open-ended responses and inquiry-based questions. For additional details regarding the UEFSP see (Barnett et al., under review).

### Study Context

The focus of the Urban Ecology Field Studies Program has been in the Boston metro area. Most students who participate in the program attend the Boston Public Schools (BPS). The Boston Public School district (18,400 students in grades 9-12), like many other urban districts that have large populations of low income and minority students (64% of the students in BPS are African-American or Hispanic, 62% are eligible for the free lunch program, and 9% for reduced price meals), are engaged in a whole school change reform process based on increasing subject literacy, pedagogical accountability, and the use of technology to improve teaching (Knapp & Plecki, 2001). Unfortunately, in the BPS, like other urban school districts, high-quality science teaching is often seriously compromised by under-prepared teachers, teachers teaching out of field (e.g. in BPS there are only 5 certified physics teachers for 20 high schools), insufficient materials and supplies, and lack of a structure to support innovative teaching practices (Barton, 1998). The need for improvement is pronounced and plays out in terms of test scores. For example, the latest results on the Massachusetts Comprehensive Assessment System for 10th grade science revealed that 65% of BPS students were failing, 24% needed improvement, 11% were proficient, and 0% were advanced. Couple these test scores with the demands of the recently passed school accountability measures, BPS (and all urban centers) are in need of programs that actively engage and interest students in the doing of science. Lastly, such programs are needed because research has shown that if students are interested in science they are more likely to attain higher levels of achievement (Gibson & Chase, 2002; Kahle et al., 2000).

## Methods

### Population and Samples

Students participating in the Urban Ecology Field Studies Program have a wide range of academic needs and abilities. Some are honors students in Advanced Placement science classes and others are eligible for special education displaying mild to severe disabilities including students who have cognitive and physical disabilities. However, most of the students who participate in the Urban Ecology Field Studies Program are from inner-city Boston middle and high schools, predominately African-American, and many have been identified as at risk for school failure due to academic and/or behavioral difficulties.

A pre-test questionnaire was administered to a randomly selected 418 participating UEFSP students and 228 students not participating in the program (control group). Then, at the end of the academic year the same questionnaire was administered to 355 UEFSP students and 184 control group students. The control group students were randomly selected from schools that had students participating in the UEFSP and were selected from students enrolled in a science class. Given the non-traditional nature of the UEFSP and the movement of students within the Boston Public Schools it was extremely difficult to administer the pre-post surveys to the same students. Therefore, in terms of our findings we speak in terms of local programmatic effects rather than generalized ones.

### Data Collection

Data collection consisted of a mixed methodological strategy. Starting in the Fall of 2001, at the beginning of each academic semester, a subset participating students were administered a modified version of the Scientific Attitude Inventory II (Moore & Foy, 1997). The survey was modified to meet our specific local and contextual needs. The final survey consisted of 63 questions designed to measure students' interest toward science, and their understanding of scientific investigative methodologies. In addition to this quantitative data, students (N=30) were interviewed at the conclusion of their particular UEFSP project to better understand their perspective on how their participation influenced their thinking. The participating teachers (N=25) were also interviewed to understand their perspectives regarding how participation in the UEFSP influenced their students' thinking toward the environment, their ability to conduct scientific investigations, and if they had observed a change in their students' interest in science. The interview protocol consisted of a set of semi-structured questions designed to provide data regarding the teachers' perceptions of the strengths and weaknesses of the field studies program.

### Data Analysis

The quantitative data was analyzed using SPSS and the qualitative data was analyzed using a grounded theory approach to look for commonalities across the student and teacher interviews with the goal of determining which particular aspects of the program were most valuable from the participants' viewpoint and what areas of the program needed improvement. For the first year of data collection (Fall 2001 – Spring 2002) an initial exploratory factor analysis was conducted and four scales were identified: (1) I want to be a scientist, (2) Science methodology, (3) Science as an authority, and (4) Ecological mindset (only tested in the Spring 2002). The first two scales both had a reliability of 0.74. The latter two scale reliabilities were below 0.45. However, by removing the questions that had a low Point Biserial correlation (17 questions were removed) we reduced the scales and increased the reliabilities of each scale to 0.82, 0.81, 0.58, and 0.60 respectively. During second year of data collection a similar statistical approach was used with the improved survey. The same scales were identified again with reliabilities of _ = 0.85, _ = 0.82, _ = 0.67, _ = 0.76 respectively. Using the reduced scales for both the control and the experimental groups we conducted independent samples t-tests to determine if there were any differences between the two experimental and control groups. We then conducted a more fine-grained analysis by examining the differences on each question under each scale between the experimental and control groups and re-examined the interview data to develop a better understanding of why particular aspects of the program were more or less effective.

## Findings and Results

During the first year our results indicate that at the start of the academic year there were no significant differences on the scales Science methodology and Science as an authority between the experimental and the control groups. The control group scored statistically significantly higher on the scale "I want to be a scientist" than the experimental group did (See Table 2). At the end of the academic year while the control group scored significantly lower on the "I want to be a scientist" scale than it did in the Fall, the experimental group showed significant increase in their scores on the "I want to be a scientist" and the "Science methodology" scales. No significant differences were observed on the "Science as an authority" scale for either of the groups (See Table 2). In addition, on the "Ecological mindset" scale, which was tested only in the Spring the experimental group showed statistically significant higher scores. The lack of statistically significant difference in the Spring between the experimental and control groups (see Table 1) can most likely be attributed to the decrease in sample size for the Spring control group.

Table 1: Comparison of all Control with Experimental students

| | | Fall 2001 | | | | Spring 2002 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Scale | Group | N | Mean | Std. Dev | t-test | N | Mean | Std. Dev | t-test |
| I want to be a scientist | Experimental | 137 | 2.87 | .86 | -4.35* | 129 | 3.12 | .84 | 1.04 |
| | Control | 193 | 3.28 | .85 | | 56 | 2.98 | .65 | |
| Science methodology | Experimental | 137 | 3.26 | .39 | -1.5 | 129 | 3.51 | .61 | 1.52 |
| | Control | 193 | 3. 33 | ..41 | | | 3.35 | .63 | |
| Science as an authority | Experimental | 137 | 2.68 | .57 | -0.73 | 56 | 2.80 | .71 | .11 |
| | Control | 193 | 2.73 | ..65 | | | 2.79 | .67 | |
| Ecological mindset | Experimental | N/A | N/A | N/A | N/A | 129 | 3.32 | .60 | 2.52* |
| | Control | | | | | | 3.08 | .54 | |

*$p < 0.05$

In the second year of the program our results (see Table 2) indicate that at the start of the academic year there were no significant differences on the four scales between the experimental and control groups. At the end of the academic year while the control group scored significantly lower on all of the scales whereas the experimental group scored higher on the “I want to be a scientist” scale and “Ecological mindset” than on the pre-test. Further, comparison of the experimental and control group scores revealed that the experimental group significantly outperformed the control group on the “I want to be a scientist”, “Scientific Methodology”, and “Ecological Mindset” scales. There was no significant difference between the two groups on the “Science as an Authority” scale. Even though the experimental group outperformed the control group on three of the four scales it is important to note that the experimental group post-test scores were not significantly different than the pre-test scores. Therefore, a further examination was undertaken to better understand our results. Specifically we examined gender effects of our program. This analysis revealed that males ($N_{exp} = 128$, $N_{control} = 60$) in the experimental group significantly outperformed control group males on the post-test on the “Scientific Methodology” ($t=6.20$, $p<.05$) and Ecological mindset ($t=4.34$, $p<.05$) scales. Analysis of the female responses ($N_{exp} = 127$, $N_{control} = 48$) revealed that the experimental female group significantly outperformed the control on the “Scientific Methodology” ($t=3.73$, $p<.05$) and the “I want to be a scientist” ($t=2.10$, $p<.05$) scales. Further, analysis of the female response showed that the experimental group improved on all four scales whereas female students in the control group scores decreased on all four scales. Thus, participation in the UEFSP appears to maintain participating males’ interest science, improve males understanding of the scientific process and their sense of stewardship. Participation in the UEFSP program also appears to improve female student understanding of the scientific process and their interest in science.

Table 2: Comparison of Control and Experimental groups during Fall 2003 – Spring 2003

| | | Pre-Test (Fall 2002) | | | | Post-Test (Spring 2003) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Scale | Group | N | Mean | Std. Dev | t-test | N | Mean | Std. Dev | t-test |
| I want to be a scientist | Experimental | 418 | 3.16 | .82 | .12 | 355 | 3.1 | .81 | 2.6* |
| | Control | 228 | 3.15 | .86 | | 184 | 2.88 | .77 | |
| Science methodology | Experimental | 418 | 3.82 | .47 | 1.47 | 355 | 3.75 | .55 | 5.9* |
| | Control | 228 | 3.76 | .55 | | 184 | 3.4 | .77 | |
| Science as an authority | Experimental | 418 | 2.66 | .66 | 1.2 | 355 | 2.76 | .68 | .223 |
| | Control | 228 | 2.60 | .65 | | 184 | 2.77 | .64 | |
| Ecological mindset | Experimental | 418 | 3.51 | .62 | .59 | 355 | 3.48 | .59 | 4.60* |
| | Control | 228 | 3.48 | .64 | | 184 | 3.2 | .63 | |

*$p < 0.05$

Upon an analysis of individual questions and the interview data we found emergent themes that suggested students participating in the program began to change their perspectives regarding stewardship of their local environment as noted by a Boston Public High teacher during an interview:

> They [the students] have a heightened sensitivity to trash on “their” field site once it becomes theirs. They start to think about it proactively, even asking on their own if we could bring out materials to do a clean-up.

Most urban students do not see science as relevant to their daily lives for a myriad of reasons (Fusco, 2001) however, through participation in the UEFSP many students commented that they recognized science as a tool that they can use to understand the world around them as noted by one inner city student:

> I’d like to do some science work but the Neponset River was kind of dry… This is a question I’d like to ask: Why weren’t there a lot of creatures out there… no nothing … it was just dry… it was just water. I’d like to know what’s up with that.

Teachers also observed that students’ self-confidence in doing science increased as a result of participating in the program. This was noted by a Boston Public High school teacher during an interview:

> One day they were all walking out to the field with the testing equipment, and the students were bragging to other students in the hallway that they were going to do “real science” outside. Students are usually excited to go out to the field site.

The participating teachers were also excited that over time their students succeeded and collected significant amounts of data, analyzed the data, and presented their work at the year-end conference. One teacher commented:

> A lot of people said inner city kids can't do science and they proved them wrong. Our kids enjoy being out in the environment and I hope next year we'll get more opportunities to do that.

Perhaps most important was that science became accessible to urban youth through observations, discussion about real world problems impacting their neighborhoods, and through sustained involvement in locally relevant scientific investigations throughout the year. Not surprisingly, such experiences were seen as having little in common with school science as noted by one student:

> We had a better learning experience out there doing science rather than inside hoping to see it!

In short, participation in the field-based program provided the students with one of their few scientific laboratory experiences (many schools in the city either do not have laboratories or do not have equipment) and as such provided them with exposure and the opportunity-to-learn (Tate, 2001) both of which are critical for students to reach their potential.

## Educational Implications

Students in urban schools (as well as students with special needs) have often been denied access to high-quality opportunities for learning science (Tate, 2001). The research on urban school science has revealed that high quality urban science teaching is often seriously compromised by teachers teaching out of field, insufficient materials and supplies, and lack of a structure to support innovative teaching practices (Barton, 1998). This set of affairs, in turn, leads to poor achievement as documented by Teel, Debruin-Pareck, & Covington, (1998) where they found that "one of the most important causes of African American students' low achievement in school is inappropriate teaching strategies." Therefore, given the constraints of urban school settings it is necessary to broaden the focus of urban science education. One way is to involve students directly in real-world community science projects like the UESFP. Such an approach not only reflects contemporary inquiry-based science education reforms (Hogan, 2002), but also strengthens the connections between school science and the real world (Barton, 2001), by allowing students to use the city around them as a natural laboratory. Further, this approach to science education has the potential to attract more urban students into the sciences once they begin to believe they can do science and understand that science is interwoven with their everyday lives (Fusco, 2001; National Science Foundation, 1998). The work presented here describes the impact of field-based out-of-school experience had on urban student interest toward science, their sense of stewardship, and their intellectual self-confidence to do real-world science.

Achieving equity in terms of science instruction is particularly important in urban school districts given that urban school districts like the Boston area schools educate 25% of all school-age students, 35% of all poor students, 30% of all English-language learners, and nearly 50% of all minority children (Pew Charitable Trusts, 1998). Lastly, current science education reform policies and practices emphasize the importance of developing deep understandings of science concepts and skills, the interdisciplinary nature of science and technology, the role and importance of science in everyday society, and the urgency of providing new points of entry for high poverty, urban youth to move into science trajectories. Implicit in these initiatives is the embedded assumption that teachers know how to build deep connections between the worlds of their students and the worlds of science by identifying and enacting standards-based curriculum, while also responding to increasing demands from district, state and federal policymakers for teacher and student accountability. The program described in this manuscript attempts to achieve that elusive goal of building a program that fits within existing urban school district structures while providing the opportunity for every student to learn and engage in science.

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