


SCIENCE EDUCATION & CIVIC ENGAGEMENT

AN INTERNATIONAL JOURNAL

VOLUME 6 ISSUE 1 · WINTER 2014

Science Education and Civic Engagement: An International Journal
Volume 6 : Issue 1, Winter 2014
ISSN: 2167-1230

Publisher
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Partial support for this Journal was provided by the National Science Foundation's Course, Curriculum and Laboratory Improvement Program under grant DUE 0618431. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily represent the view of the National Science Foundation or the National Center for Science and Civic Engagement.

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PROJECT REPORT

From the Editors

We are pleased to announce the publication of the Winter 2014 issue of *Science Education and Civic Engagement: An International Journal.* This issue contains four project reports that illustrate a variety of creative approaches to liking science education and civic engagement.

Peter Bower (Barnard College) and colleagues describe the dissemination of a SENCER model curriculum based on the *Brownfield Action* simulation. This project was accomplished by establishing a STEM education network of 10 colleges, universities, and high schools. The curriculum was adapted and implemented for a variety of different student groups, from introductory general education science courses to upper-level courses on environmental site assessment. The collaborative network described in this article provides a successful model for dissemination of innovations in STEM education.

In a second project report, Alex T. Chow, Juang-Horng Chong, Michelle Cook, and David White (Clemson University) provide an account of a citizen scientist project that uses fireflies as an indicator of environmental quality. Counting the bioluminescent flashes of fireflies at night provides a simple way to engage students, teachers, resource managers and members of the local community in creating a collaborative firefly survey. The article describes the implementation and outcomes of a three-year project that includes service-learning, sustainability, and environmental stewardship.

In the third article, a team of faculty members and civic engagement professionals from Southwestern University—Meredith Liebl Kate Roberts, Amanda Mohammed, Megan Lowther, Erica Navaira, Anna Frankel, Suzy Pukys and Romi L. Burks—describe a partnership with local elementary schools to integrate science into an affordable afterschool program. After participating in a 10-week initiative called Science and Math Achiever Teams (SMArTeams), elementary school students showed gains in confidence, experimental design, curiosity and science enjoyment. Future directions for this project include the development of strategies to broaden elementary students' awareness of STEM career pathways.

The final project report in this issue is provided by a team of educators at the United States Military Academy at West Point. Matthew Baideme, Andrew Pfluger, Stephen Lewandowski, Katie Matthew, and Jeffrey Starke established a curriculum linkage between an environmental engineering course and a marketing course, with the goal of developing students' skills at researching complex environmental issues. Students from the two courses collaborated on a semester-long project to develop sustainable environmental solutions to address community needs. A pre/post assessment of the project showed student gains in confidence, motivation, and research skills.

We wish to thank all the authors of these reports for sharing their interesting and important work with the readers of this journal.

— *Trace Jordan*
Eliza Reilly
Co-Editors-in-Chief

PROJECT
REPORT

Brownfield Action:
Dissemination of a SENCER Model Curriculum and the Creation of a Collaborative STEM Education Network

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Abstract

Brownfield Action (BA) is a web-based environmental site assessment (ESA) simulation in which students form geotechnical consulting companies and work together to solve problems in environmental forensics. Developed at Barnard College with the Columbia Center for New Media Teaching and Learning, BA has been disseminated to ten colleges, universities, and high schools, resulting in a collaborative network of educators. The experiences of current users are presented describing how they have incorporated the BA curriculum into their courses, as well as how BA affected teaching and learning. The experiences demonstrate that BA can be used in whole or in part, is applicable to a wide range of student capabilities and has been successfully adapted to a variety of learning goals, from introducing non-science-literate students to basic concepts of environmental science and civic issues of environmental contamination to providing advanced training in ESA and modeling groundwater contamination to future environmental professionals.

Introduction

Brownfield Action (BA) is a web-based, interactive, three-dimensional digital space and learning simulation in which students form geotechnical consulting companies and work collaboratively to explore and solve problems in environmental forensics. Created at Barnard College (BC) in conjunction with the Columbia Center for New Media Teaching and Learning, BA has been used for over ten years at BC for one semester of a two-semester Introduction to Environmental Science course that is taken each year by more than 100 female undergraduate non-science majors to satisfy their laboratory science requirement. BA was selected in 2003 as a "national model curriculum" by SENCER (Science Education for New Civic Engagements and Responsibilities), an NSF science, technology, engineering, and mathematics (STEM) education initiative. The BA curriculum replaces fragmented, abstract instruction with a constructivist interdisciplinary approach where students integrate knowledge, theory, and practical experience to solve a complex, multifaceted, and realistic semester-long interdisciplinary science problem. The overarching themes of this semester are civic engagement and toxins, focusing on toxification of the environment, pathways taken by environmental toxins, and the impact of toxins on the natural environment and on humans. Readings that have been used to complement teaching using BA include Jonathan Harr's *A Civil Action* and Rachel Carson's *Silent Spring.*

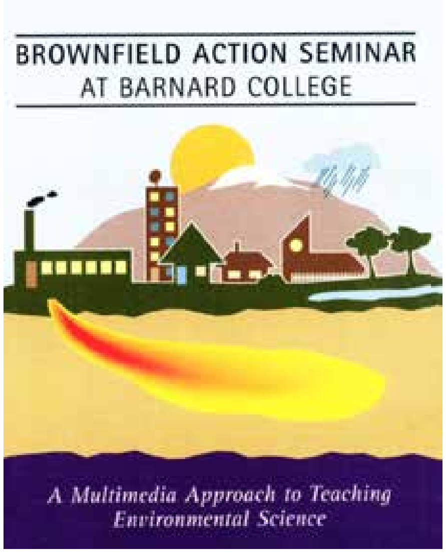


FIGURE 1. Call for a Brownfield Action Seminar using the Brownfield Action logo that shows a contaminant plume from a factory migrating in the saturated zone of an aquifer.

The pedagogical methods and design of the BA model are grounded in a substantial research literature focused on the design, use, and effectiveness of games and simulations in education. The successful use of the BA simulation at Barnard College is fully described in Bower et al. (2011). This article describes multiple formative assessment strategies that were employed using a modified model of Design Research (Bereiter 2002; Collins 1992; Edelson 2002), culminating in a qualitative ethnographic approach using monthly interviews to determine the impact of BA on the learning process. Results of these ethnographies showed at a high confidence level that the simulation allowed students to apply content knowledge from lecture in a lab setting and to effectively connect disparate topics with both lecture and lab components. Furthermore, it was shown that BA improved student retention and that students made linkages in their reports that would probably not have been made in a traditional teaching framework. It was also found that, in comparison with their predecessors before the program's adoption, students attained markedly higher levels of precision, depth, sophistication, and authenticity in their analysis of the contamination problem, learning more content and in greater depth. This study also showed that BA supports the growth of each student's relationship to environmental issues and promotes transfer into the students' real-life decision-making and approach to careers, life goals, and science (Bower et al. 2011).

BA is one of a small but growing number of computer simulation-based teaching tools that have been developed to facilitate student learning through interaction and decision making in a virtual environment. In STEM fields, other examples include CLAIM (Bauchau et al. 1993) for mineral exploration; DRILLBIT (Johnson and Guth 1997) and MacOil (Burger 1989) for oil exploration; BEST SiteSim (Santi and Petrikovitsch 2001) for hazardous waste and geotechnical investigations; Virtual Volcano (Parham et al, 2009) to investigate volcanic eruptions and associated hazards; and eGEO (Slator et al. 2011) for environmental science education. These virtual simulations give students access to environments and experiences that are too dangerous, cost-prohibitive, or otherwise impractical to explore (Saini-Eidukat et al. 1998). Through directed role play they also provide opportunities for social interaction and student inquiry into the human element of technical analysis and decision making (e.g., Aide 2008).

What makes the Brownfield Action SENCER Model Curriculum unique among these STEM online simulations is that it includes a significant component of engagement with the civic dimensions of environmental contamination, interwoven with the technical investigations being conducted by the students. The BA simulation is also unique in that it has been disseminated to ten colleges, universities, and high schools, and a collaborative community of users has developed. To the best of our knowledge, BA is the only SENCER national model curriculum with a network of faculty collaborating in a community of practice. Moreover, this network has adapted the original simulation and its related products for use with a widening diversity of students, in a variety of classroom settings, and toward an expanding list of pedagogical goals. This paper documents the experiences of ten teachers and professors (in addition to those at Barnard College) who are using BA to improve student learning and teaching efficacy, to improve retention in the sciences, and to increase student motivation and civic engagement. All of these teachers and professors have shared their experiences, course materials, and curricula developed using the BA simulation in their courses, and the evolution of this collaborative network has now begun to define the direction that BA is taking. Currently the network consists of environmental scientists, an environmental engineer, a sociologist, geologist, GIS specialist, a smart growth and landscape architect, and high school science teachers, all sharing the goal of teaching science from the perspective of promoting civic engagement and building a sustainable society. Team members have developed course content specific to their individual fields of expertise and have made their course materials available to the community. The goals of this collaborative network also include telling the story of the dissemination of BA and thereby encouraging the dissemination of other successful SENCER model curricula. Ongoing efforts are being made to expand the BA network, especially among the hydrogeologic, brownfield, and environmental site assessment community. The BA SENCER Team has also begun to develop BA for use in online education.

The purpose of this paper is to present the collective experiences of the college and university faculty and high school teachers who have incorporated the BA simulation and curriculum into their courses. The experiences using BA reported here demonstrate how the BA simulation can be adapted for use, in whole or in part, for a wide range of student capabilities, and the authors describe how BA affected student learning and satisfaction. The descriptions that follow include applications of the BA simulation to environmental instruction at the high school level (Liddicoat, Miccio, Greenbaum), to the fundamentals of hydrology and environmental site assessments at an introductory to intermediate undergraduate level (Bennington, Graham), and to training both undergraduate and graduate students in advanced courses in hydrology and environmental remediation (Lemke, Lampoousis, Datta, Kney). Although many of the applications reported here apply to courses in STEM curricula, BA is not restricted in its utility to teaching students with advanced STEM skills. Rather, BA has proven to be equally effective whether it is used to introduce non-science-literate students to basic concepts of environmental science and basic civic issues of environmental contamination or to provide advanced training in environmental site assessments and to model groundwater contamination to future environmental professionals.

For interested instructors, information about BA and a guided walkthrough of the simulation can be found at www.brownfieldaction.org. By contacting the lead author (Bower), one can obtain a username and password to access the simulation, see the library of documents, maps, and images related to the simulation and its use in the classroom, and visit the "User Homepages" where the authors from the collaborative network describe their use of BA in more detail than is done in this paper and provide additional documents and maps. These instructors have expanded the pedagogy of BA by utilizing the simulation in unique ways and in contributing new curriculum. In the "User Homepages," new or potential users can find an instructor whose use of BA parallels their own, begin a dialogue, and become part of the collaborative network.

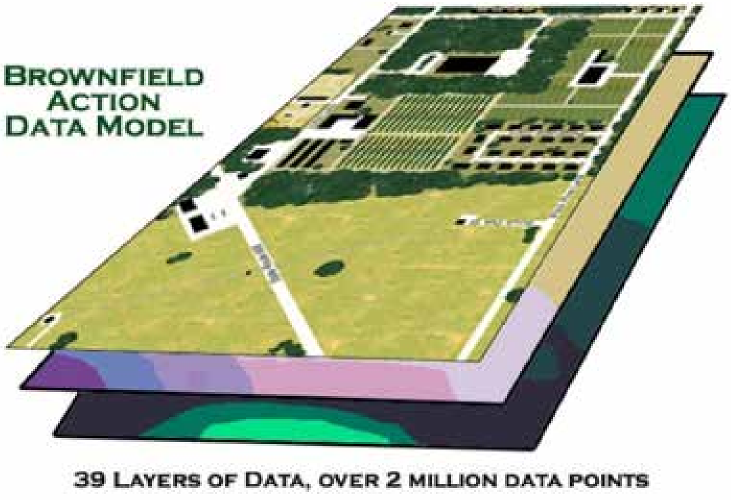


FIGURE 2. Data can be obtained for surface and bedrock topography, water table, water chemistry, soil characteristics, and vegetation as well as data from tools like soil gas, seismic reflection and refraction, metal detection and magnetometry, ground penetrating radar, and drilling.

Teaching High School Students the Fundamentals of Environmental Science

Joseph Liddicoat, *Barnard College*

Using the interactive, web-based Brownfield Action simulation, a total of 48 public high school students from the five boroughs of New York City who were enrolled in the Harlem Education Activities Fund (HEAF) were taught environmental science in a way that combines scientific expertise, constructivist education philosophy, and multimedia during 12-week programs in the fall of 2009, 2010, and 2011 at Barnard College. In the BA simulation, the students formed geotechnical consulting companies, conducted environmental site assessment investigations, and worked collaboratively with Barnard faculty, staff, and student mentors to solve a problem in environmental forensics. The BA simulation contains interdisciplinary scientific and social information that is integrated within a digital learning environment in ways that encouraged the students to construct their knowledge as they learned by doing. As such, the approach improved the depth and coherence of students' understanding of the course material.

In Barnard's partnership with HEAF, BA was used in modular form to gather physical evidence and historical background on a suspected contamination event (i.e., leakage of gasoline from an underground storage tank) that resulted in the contamination of the aquifer in a fictitious municipality, Moraine Township. The HEAF students assumed the role of environmental consulting firms with a fixed budget to accumulate evidence about a parcel of land intended for a commercial shopping mall and to report the feasibility of using the property for that purpose. Through the integration of maps, documents, videos, and an extensive network of scientific data, the students in teams of three and working with a Barnard undergraduate mentor engaged with a virtual town of residents, business owners, and local government officials as well as a suite of geophysical testing tools in the simulation. Like real-world environmental consultants, students had to develop and apply expertise from a wide range of fields, including environmental science and engineering as well as journalism, medicine, public health, law, civics, economics, and business management. The overall objective was for the students to gain an unprecedented appreciation of the complexity, ambiguity, and risk involved in investigating and remediating environmental problems.

The Barnard undergraduate mentors were familiar with BA from doing the simulation as part of an introductory science course. The mentoring included weekly assistance with writing and mathematical exercises, and guidance in writing a Phase I Environmental Site Assessment report that was required of each HEAF student. Assessment of the program included weekly journals reviewed by one of us (RK) at Columbia University's Center for New Media Teaching and Learning. The student mentors also provided information throughout the program on the progress of the students and their role in the program.

Overall, the students responded well to computer-based learning, especially the students who perceived themselves to be visual learners. Videos were especially effective in the instruction, as were hands-on laboratory activities (e.g., sieving of sand, permeability measurement exercise, measuring movement of a fictitious underground plume in a water model) as evidenced by open-ended journal responses from the students. One additional activity mentioned by nearly every participating student was the weekend retreat to Black Rock Forest, a 3,830-acre second-growth forest near West Point, NY, which Barnard helps to support. This retreat provided the HEAF students an opportunity to interact informally with each other and the HEAF staff, their mentors, and the Barnard instructors. Those two days allowed immersion in topics about geology, biology, botany, and ecology that the students did not encounter in the urban environment they lived in. As the 12-week program progressed, students frequently expressed their concern about gas stations in their neighborhood, which is a potential form of brownfield known to all of them. An indication of sustained interest in the program was the high percentage of student attendance, considering the students' sometimes difficult commute on public transportation from the five boroughs to Barnard within an hour of when they were dismissed from their high school. Average weekly attendance was 91% in year one, 98% in year two, and 92% in year three. Recommendations made by student mentors based on their experiences with the program include the suggestion that the mentors be utilized more fully in the instructional process to allow them to provide more context and other scaffolding support during group work time. This would allow for less large group lecturing and more peer instruction, as participants reported benefitting more from structured group time with mentor guidance than from the full group lecture components of the curriculum.

Briane Sorice Miccio, *Professional Children's School*

Brownfield Action has been used for four years in a high school Environmental Science class consisting of students in grades 10, 11, and 12. The class met 40 minutes each day, five days a week for seven weeks. During this time, the students investigated the gasoline plume emanating from the BTEX gas station and then wrote a Phase II ESA.

BA has been an invaluable tool in demonstrating many of the concepts covered in the curriculum. It has given the students a "hands-on" opportunity to put into practice the topics and skills they have learned. They were able to study a number of concepts, including groundwater movement (porosity, permeability, D'Arcy's Law), topography and contour mapping, and the chemical and physical properties of gasoline, while simultaneously experiencing how the knowledge of these concepts can be applied in a real-world situation. There was also an in-class demonstration of the movement of a contamination plume through a cross section of an aquifer, as well as a sediment size analysis using sieves to separate a sediment sample "taken" from the ground near the BTEX gas station. Students were able to physically see the different components of sediment and relate the different sized particles to the speed with which groundwater, and any inclusive contamination, is able to flow. With BA, students are able to learn, apply their knowledge in an ongoing interdisciplinary exercise, and see how all of these separate concepts taught in environmental science class tie together in the real world.

The Environmental Science course has been taught for seven years with BA being used for the past four years. BA made a tremendous difference, satisfying both the goals of the curriculum as well as enhancing student interest. Students are given the opportunity to investigate the environmental, social, and economic issues facing a community that is forced to deal with a brownfield and contamination of the local environment. New York City has over 40,000 brownfield sites, many of which are unknown to its residents. When students who live in the city work with BA, whose narrative deals with the ramifications of contamination in a small town, they are able to gain a better understanding of the magnified ramifications in a larger city. This, in turn, will make them socially aware of the effects of a brownfield on the people surrounding it.

Typically, students execute the "learn and apply process," where they learn in class and apply these concepts to a one-time lab exercise and exam before moving on to the next topic. However, with BA, the students are enthusiastic about applying what they have learned in a more interesting, realistic, and interactive format. Since the implementation of BA, students have been more receptive, and it has sparked more questions and comments than ever before. The students' questions have also demonstrated a deeper understanding of the subject matter than with traditional textbook work. The students are also able to incorporate problem-solving skills, exercise leadership skills and management strategies, and work collaboratively. Moreover, they are able to recognize the social and economic ramifications of pollution. In addition, BA's demonstration of the work of an environmental site investigator has, on more than one occasion, inspired students of mine to pursue the field of environmental science in college. Since my students are all college bound, the fact that Brownfield Action inspires interest in this field, particularly now when we need the next generation to be environmentally conscious, is gratifying and demonstrates the value of Brownfield Action within a high school curriculum.

Bess Greenbaum, *Columbia Grammar and Preparatory School*

Columbia Grammar & Prep is a private K-12 school in Manhattan, NY. The Brownfield Action simulation was utilized in two sections of the yearlong environmental science elective course, open to juniors and seniors. (One section had nine students; the other had 14. All of the 23 students were in either 11th or 12th grade, except for one in 10th grade). The high school students investigated the gasoline plume and associated drinking water well contamination portion of BA simulation. The goal of the project was to engage the students in some real methodologies used to detect and delineate contaminant plumes.

Students completed the investigation in teams of two or three over seven weeks. Groups were chosen by the instructor, who had, at this point, a fairly good sense of each student's ability and motivation level. In order to avoid the common pitfall of one student in the group doing all the work, students were grouped according to similar ability and motivation levels. This was a successful tactic. First, students were introduced to the concepts of brownfields and superfund sites. Then, they were shown how to log onto and navigate the BA computer simulation and the features for each new test. The students found the online interface to be very user-friendly.

Each team conducted tests and made maps of the gasoline plume, but each student was responsible for submitting their own final four- to six-page report along with four hard-copy maps. One map was a basic site map, and three were topographic maps of the site highlighting different data: surface topography, bedrock topography, and water table elevations. Students utilized two tests for contamination provided in the simulation: soil gas sampling and analysis and drill/push testing. Prior to conducting these tests, the instructor spent two or three class periods discussing with the students the major components and characteristics of gasoline. Students discovered that gasoline is a mixture of many substances, each with its own physical and chemical properties. We discussed that gasoline contained floating, volatile, and water soluble parts. For this investigation, we focused on two tests for the presence of gasoline provided in the simulation. First, the Soil Gas Sampling and Analysis (SGSA) tested for hexane, a volatile component found in the air pockets of the soil. The second test detected the presence or absence of benzene, a water-soluble component. Once the presence of hexane in the soil was confirmed, students used the Drilling and Direct Push test to see if there was any benzene in the groundwater. Students learned that the tests were performed in this order because it was financially practical; if gasoline had not been present in the soil, it would have likely been wasteful to perform the more expensive and time-consuming test on the groundwater. The final report submitted by each student had three main parts: (1) a summary letter to the EPA outlining reasons for, and results of, their investigation; (2) a description of investigation methods, testing procedures, and data; and (3) analysis and interpretation of the data.

Students varied widely in their spatial visualization abilities. Some were quite challenged by creating and understanding the meaning of the hand-drawn topographic maps. While tedious, this tactile and methodical process improved student understanding of mapping; however, comprehending the meaning of the aerial view of the plot of the hexane data (from soil gas measurements) and the cross-sectional view of the benzene data in the groundwater contaminant plume was not so obvious for some. The concept that each contamination map represented a different orientation (either cross-section or aerial view) of the contaminant plume was repeatedly emphasized. Students understood why there was a need to test for a volatile compound (hexane) in the soil and a soluble one (benzene) in the water table, but their understanding of sediment properties and the movement of groundwater was simplistic.

The BA simulation was a good classroom experience. Based on observations, students enjoyed the self-paced group work. Two adjustments for future use are suggested. First, introduce exercises in spatial orientation earlier on in the year. This would help students grasp the concept of topographic maps more easily, and they would be better equipped to identify and draw contour lines based on elevation points. Second, the experience could be enhanced with hands-on demonstrations of sediment size class and porosity/permeability of different sediments. These adjustments would likely allow students to take a more independent role in the investigation, and require less instructor guidance as they investigate the task at hand.

Although students were given a budget, the focus was on completing the Phase II investigation—regardless of cost. Some students were initially mindful of how much each test cost, but once they knew that it did not really matter how much they spent, they no longer paid attention to this feature of the simulation. Students did, however, take advantage of the Moraine township history and interviews with the citizens in order to make their final assessment and report. Another tactic that might improve student autonomy and the BA experience would be to have them work together to figure out the most logical order of steps to take in the investigation process. A class discussion of crime shows or *A Civil Action* would facilitate this. Once they reach consensus on a logical way to carry out the investigation, they could be introduced to the simulation's tools.

Teaching Environmental Science Students Fundamentals of Hydrology and Environmental Site Assessment

Bret Bennington, *Hofstra University*

Brownfield Action (BA) is used throughout the entire semester in both an undergraduate hydrology course (Hydrology 121) and a graduate hydrogeology course (Hydrogeology 674). These are combined lecture/laboratory courses taken by students pursuing degrees in geology, environmental science, or sustainability studies, most of whom are motived by an interest in applying science to solving environmental problems but who have little prior experience in groundwater science. Students are assigned to groups of three or four to form consulting teams. Teams are provided class time each week during laboratory to meet and coordinate online work performed individually outside of class hours. Students use the simulation to conduct a Phase I ESA (Environmental Site Assessment), and each group is required to make a presentation to the rest of the class detailing their findings and to submit a Phase I ESA report midway through the term. During the second half of the semester the teams work on a Phase II investigation. Final group presentations communicating the results of the Phase II investigation are made at the end of the term, and each student is required to submit an individual Phase II ESA report for evaluation. Students use critical feedback from the assessment of the Phase I materials to improve their Phase II presentation and reports.

A useful attribute of the BA simulation is that important hydrologic concepts introduced in lectures and labs can be incorporated into different stages of the online BA investigation, providing students the opportunity to practice applying these concepts in realistic, problem-solving activities. For example, in one laboratory exercise, students measure the porosity and hydraulic conductivity of a sediment sample obtained (hypothetically) from the abandoned Self-Lume factory site in the BA simulation. In another exercise, students learn how to calculate the direction and magnitude of a hydraulic gradient from hydraulic head data collected from monitoring wells. As part of their Phase I and Phase II investigations, students use these sedimentological measurements and groundwater analytical methods, in combination with data obtained in the online simulation, to calculate flow volume and seepage velocity beneath the Self-Lume site to assess potential impacts to the town water supply well. Students must also incorporate into their investigations knowledge of groundwater law and the regulations and standards governing environmental investigations, methods of aquifer testing and analysis, and the behavior of different forms of groundwater contaminants. To complete their ESA investigations within the BA simulation, students are thus required to integrate a wide range of data, methods, and concepts learned across the course.

Navigating the BA simulation also introduces students to the different components of civil government and the variety of agencies and departments involved in regulating and maintaining public health and groundwater quality. Students are drawn into the simulation by the authenticity of the online world provided, which is supported by realistic, richly detailed documents, newspaper articles, videos, and video and text interviews with public officials. It is a revelation to most students that so much useful information on potential environmental problems can be obtained just from interviews and municipal documents. In addition, the BA simulation provides many opportunities for students to develop critical thinking and problem-solving skills, as well as professional and technical skills, most importantly the ability to interpret, summarize, and effectively communicate technical information. As part of their course requirements, students must produce two formal, professionally written and formatted technical reports, and one informal and one formal oral presentation, and they must draft topographic, water table, and bedrock contour maps, as well as maps summarizing data from different aquifer tests and analyses. Finally, students gain valuable experience working cooperatively as part of a team focused on solving problems on time and within a reasonable budget. (Student teams are billed for all activities within the simulation and are assessed on how cost-effective their investigations are.)

In the past year and a half students were surveyed to determine their perceptions of the effectiveness of BA as a teaching tool. Student response to the BA simulation has been overwhelmingly positive, with a large majority of students indicating that BA was successful in facilitating student learning and providing experience with data analysis, interpretation, and problem solving (see Figure 3). More recently, in the fall of 2013, a SENCER Student Assessment of Learning Gains (SALG) instrument was deployed in the Hydrology 121 course at Hofstra University (nineteen undergraduate geology and environmental resources majors) to assess student gains in understanding and skills derived from their experiences with the semester environmental site assessment project built around the Brownfield Action simulation. Results from this assessment indicate moderate to large gains in understanding of course content (Figure 4) and relevant cognitive skills (Figure 5) learned and practiced while working with the BA simulation.

Many students report that BA increased their interest in pursuing hydrogeology and environmental consulting as a career (although some have also indicated that they learned from using BA that this was not the career path for them). Students have also reported that knowledge and experience of how to conduct Phase I and Phase II ESA investigations

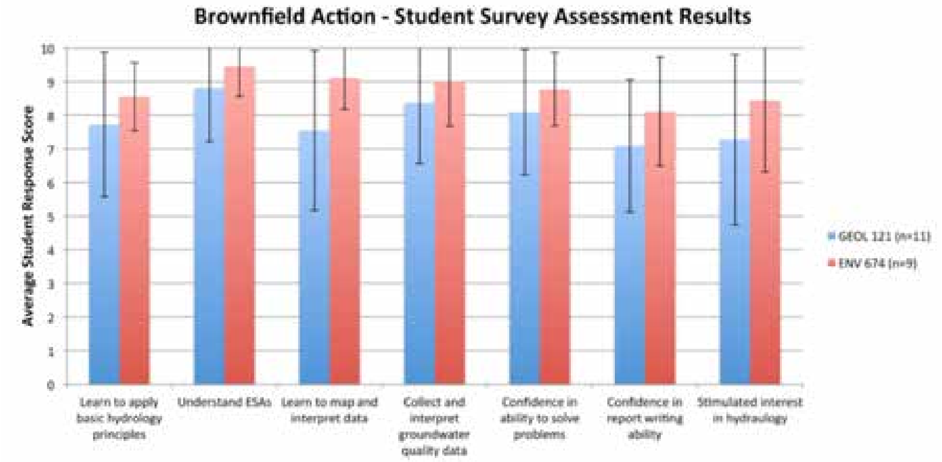


FIGURE 3. Average student responses to questions asking them to rate the effectiveness of the Brownfield Action simulation for aiding student learning. Responses ranged from 1 (most negative) to 10 (most positive). Error bars indicate average +/- one standard deviation.

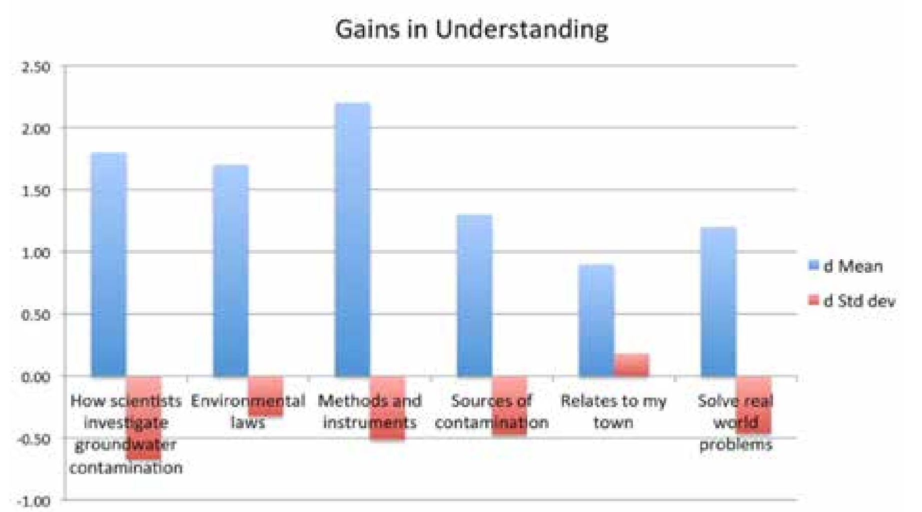


FIGURE 4. Changes from the beginning to the end of the semester in the mean (d Mean) and standard deviation (d Std dev) value of responses to questions asking students to rate their understanding of environmental and hydrologic concepts learned in the course working with the Brownfield Action simulation. An increase in the mean of the responses indicates a gain in understanding relative to a 5 point scale. A decrease in the standard deviation value indicates greater agreement among student responses.

obtained through the BA simulation have been a very positive factor in interviews for jobs in environmental consulting. As one student wrote, "The Brownfield Action simulation not only helped me define a career goal, but it also helped me land a job in the environmental field. The skills and knowledge I gained through the simulation not only made my résumé look stronger to future employers but it allowed me to impress interviewers through conversation. Many potential employers were impressed by the fact that I knew enough about federal regulations and environmental concepts to even just carry on a discussion about Environmental Site Assessments."

The BA simulation has proven to be an effective teaching tool for three main reasons. It recreates the ambiguity of real-world problem solving by providing students with an open-ended set of environmental problems, and it requires that they apply what they have learned in the classroom without ever being told exactly what to do. It provides a richly detailed and realistic virtual world that students find interesting and that engages their curiosity by presenting them with realistic environmental problems to solve. Finally, the BA simulation provides a framework for demonstrating key concepts developed in hydrology/hydrogeology courses. Because much of the lecture instruction in these courses involves the mathematical analysis of groundwater flow, the students benefit from being able to apply concepts such as hydraulic conductivity, hydraulic gradient, hydraulic head, and seepage velocity to solve applied problems within the framework of the BA simulation. This helps the students to better understand these concepts, and it greatly increases their interest and engagement in hydrogeology. Students routinely comment on how much they enjoy working in the simulation and it has inspired a number of students to pursue careers in environmental consulting and groundwater remediation.

Tamara Graham, *Haywood Community College*

Haywood Community College serves a predominantly rural community in the Appalachian Mountains roughly one-half hour west of Asheville, North Carolina. Haywood's Low Impact Development (LID) Program was launched in 2009 to provide workforce training and resources to foster more sustainable development in the region. Though

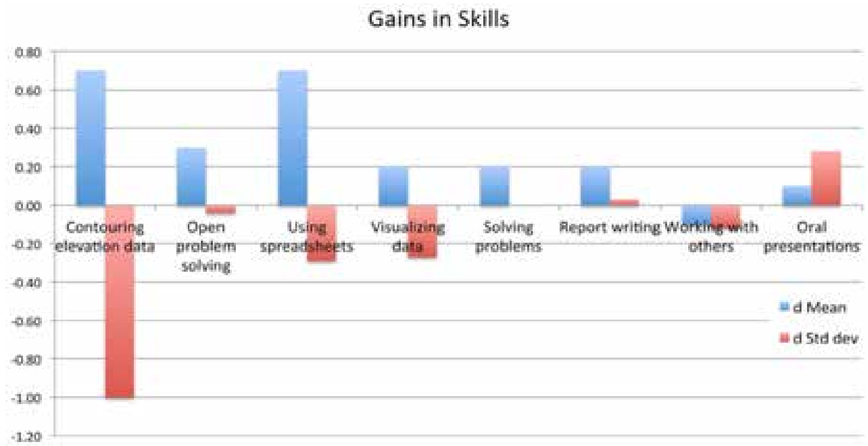


FIGURE 5. Changes from the beginning to the end of the semester in the mean (d Mean) and standard deviation (d Std dev) value of responses to questions asking students to rate their ability to apply academic skills learned or practiced in the course working with the Brownfield Action simulation. An increase in the mean of the responses indicates a gain in ability relative to a 5 point scale. A decrease in the standard deviation value indicates greater agreement among student responses.

the LID Program is relatively new, it is part of the College's highly regarded Natural Resources Management Department, which has offered two-year associate degrees and professional certificates in Forestry, Horticulture, and Fish and Wildlife for more than 40 years. The LID Program complements these established programs by offering students the opportunity to study innovative strategies for mitigating the impact of development on natural systems, particularly the hydrologic cycle.

LID 230, *The Remediation of Impacted Sites*, is a required course in the LID Program that surveys issues related to environmental contamination from the Industrial Revolution in the nineteenth century to contemporary 21st-century brownfields remediation programs:

> This course is designed to familiarize students with various scale remediation projects to enhance understanding of the role environmental repair has in sustainable development. Emphasis will be placed on case studies that cover soil and water remediation efforts necessitated by residential, commercial, industrial, governmental, and agricultural activity. Upon completion, students will be able to discuss and utilize the tools and technologies used in a variety of soil and water remediation projects. (Course description from *HCC Catalog & Handbook*)

From the perspective of LID, the remediation of brownfield sites offers communities perhaps the greatest return on investment in terms of sustainability. Brownfields are among the most contaminated sites environmentally, and their remediation spurs reinvestment in otherwise dilapidated urban areas, creating walkable, vibrant spaces for living and working where infrastructure already exists, rather than necessitating further encroachment of development on rural land or "greenfields."

In addition to a Brownfield Action (BA) training seminar held at Barnard College, the BA website contains a User Section with curriculum resources that have been have been an invaluable, engaging resource for developing Haywood's LID 230 course. In the spring semester of 2011 and 2012, BA resources were first introduced at approximately week five of the sixteen-week semester course, with a close reading of *A Civil Action*. The shared curricula and resources, such as reading guides made available in the BA User Section, provided students with compelling historical background on the origins of current brownfields programs. Building on this foundation, in the final third of the semester students worked in small teams with the simulation to develop a Phase I ESA Report and supporting topographic and inventory maps. The BA video interviews, narrative, and interactive simulation piqued student interest and facilitated understanding of the complex, interdisciplinary, even labyrinthine nature of environmental remediation. Site exploration afforded by the simulation allowed LID students to work at their own pace to cultivate attention to detail (careful detective work) while simultaneously being mindful of the bigger picture. Coupled with students' study of case studies of local remediation projects, the simulation effectively conveyed the complex and interrelated political, environmental, economic, and social factors at issue in environmentally contaminated sites and the necessity of collaboration among diverse entities to facilitate remediation and reuse.

Rather than appearing trite in the face of the somber topic, the playful nature of the simulation, with myriad puns and entertaining diversions woven through the narrative, helped to engage students and demystify the otherwise intimidating content. The fear of the effects of environmental contamination and intimidation regarding the process are perhaps the largest factors hindering collaborative public and private action to remediate sites. The BA simulation effectively addresses these barriers through its appealing, approachable format, effectively fostering collaboration among students to address complex problems and work toward solutions.

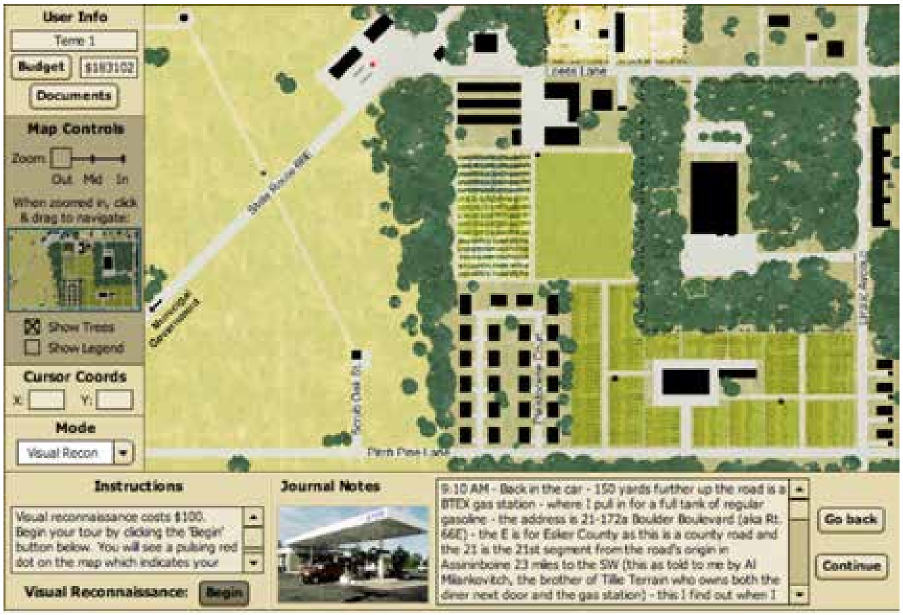
The BA simulation has provided an engaging learning opportunity for HCC's students. Several LID graduates have obtained employment with local and regional planning agencies, where their experience with the BA simulation has proven invaluable in addressing complex brownfields projects in their respective communities. HCC appreciates the opportunity to integrate this innovative simulation into our curriculum and is eager to assist Barnard College in expanding its access as an educational resource to further sustainable development goals in the region.

Douglas M. Thompson, *Connecticut College*

The Brownfield Action (BA) simulation has provided an important component of the course Environmental Studies/Geophysics 210: Hydrology at Connecticut College since the fall of 2004. Attendance at a Brownfield Action seminar the previous year showed that the simulation was an ideal means to replace a paper-based simulation used previously. As an experienced user of BA, I can confirm that it is a wonderful learning tool that has brought a very realistic group activity to my classroom. The program also does a very good job helping students develop the scientific background and confidence needed to find employment in the groundwater consulting industry. More importantly, students enjoy the BA module and learn a great deal about basic project management and group collaboration skills that apply to a range of disciplines.

My first job after college was as a Project Geologist for a groundwater consulting company in New England. It was a good first job, but my undergraduate geology major and hydrology course had not prepared me for the types of decisions faced on the job. Years later as an instructor of a hydrology course, it was important that I share my consulting experiences in order to help prepare undergraduates for what can be a very good job opportunity after graduation. The BA simulation provides an excellent replication of many of the components of a Phase I site investigation. Several former students who now work in the groundwater consulting industry have said that they greatly appreciated the background they developed using the simulation.

In my class, students are divided into groups of two or three and are asked to investigate the contamination at the BTEX gasoline station. The students are required to determine whether contamination exists and to delineate the nature, extent, and source of contamination. Students are encouraged to use the soil gas sampling and analysis tool and to determine a rough map of where volatile organic compound concentrations are highest. The students are then required to install at least three shallow wells and one deep well to document the approximate source of the contamination and direction of flow in both the horizontal and vertical directions. Drilling location and well placement are important decisions for a successful project, and students often display a great deal of trepidation when they begin to install monitoring wells. The cost of a poorly placed well is an important reason for this. As someone who has stressed over drilling holes for real monitoring wells, I know that the angst that students display is a good indication that BA realistically simulates the decision-making atmosphere. The students then use the survey instruments, sample analysis options, and the resulting data to produce maps of the BTEX gasoline contamination plume and the free-product plume. Students complete a group report that presents their findings.



Visual reconnaissance costs $100. Begin your tour by clicking the 'Begin' button below. You will see a pulsing red dot on the map which indicates your

9:10 AM - Back in the car - 150 yards further up the road is a BTEX gas station - where I pull in for a full tank of regular gasoline - the address is 21-172a Boulder Boulevard (aka Rt. 66E) - the E is for Esker County as this is a county road and the 21 is the 21st segment from the road's origin in Assiniboine 23 miles to the SW (this as told to me by Al Milankovitch, the brother of Tillie Terrain who owns both the diner next door and the gas station) - this I find out when I

FIGURE 6. The Brownfield Action "playing field" in the reconnaissance mode visiting the BTEX gas station.

To supplement the basic materials supplied with the computer simulation, the program is augmented with additional data sources and activities. Existing documents as well as newly created documents are placed as a reserve in our library to replicate the task of going to government buildings to search municipal and state records. Each group is provided with a small sample of loess and asked to classify the soil based on a textural method. Students are taken on a field trip to the campus power station to see two large underground storage tanks. A mock site visit is also made there to identify potential sources of contamination and locations where monitoring wells might be installed. The BA simulation is also used as a means to demonstrate the basic principles of Darcy's Flow and hydraulic conductivity learned in the class. The students are asked to complete an estimate of the rate of groundwater movement based on some simulated pump test data created for this purpose and the groundwater table slope they determine from their BA wells.

BA provides an excellent opportunity for students to understand how the site assessment process is approached. The simulation adds a sense of realism to the sometimes abstract topics learned. BA has become a very important component of Environmental Studies/Geophysics 210: Hydrology, and the program will be used as long as its software is viable.

Training Undergraduate and Graduate Students in Advanced Courses in Hydrology and Environmental Remediation

Larry Lemke, *Wayne State University*

Brownfield Action was originally incorporated into GEL 5000—Geological Site Assessment—at Wayne State University during the Winter-2010 semester as part of an NSF CAREER grant that focused on groundwater contamination in previously glaciated urban areas. BA continues to play an integral role in this course, which is offered to both graduate students and upper division undergraduates and typically attracts 20 to 24 students each time it is offered. BA forms the basis for a term project in much the same way that it is employed at Barnard College: teams of students at Wayne State use the BA simulation as the basis for formulating Phase I and Phase II Environmental Site Assessments and reports.

In the first phase, students strictly follow ASTM Standard E 1527-13 (formerly E 1527-05). After completing site reconnaissance, records review, and interviews (no sampling is allowed except for Topographic Surveys), students document their findings, opinions, and conclusions following the ASTM specified report format. In the second phase, students choose two Recognized Environmental Conditions (RECs) to be investigated following ASTM Standard E 1903-11. The 2011 revision of this standard prescribes application of the scientific method to evaluate RECs. To begin this process, students must schedule an interview with their client (the course instructors) to recommend *Objectives*, *Questions* to be answered, *Hypotheses* to be tested, *Areas* to be investigated, a *Conceptual Model* for contaminant migration including target analytics, a proposed *Sampling Plan*, and an estimated *Budget*. During the interview, one course instructor plays the role of a naïve business manager focused on liability and budget issues, while the second course instructor plays the role of an environmental manager who asks probing technical questions. After receiving client authorization, student teams proceed to implement their sampling plan and complete the Phase II ESA. In our experience, the role play exercise adds another realistic dimension to the BA simulation by providing students practice in communicating technical information and recommendations to clients in an oral format (in addition to writing professional reports).

Most recently, Gianluca Sperone, a co-instructor in the WSU course, developed an effective innovation by utilizing ESRI ArcGIS tools to perform the Phase I ESA analysis. After converting available materials from the BA simulation into ArcGIS Geodatabase format, he mapped the information accessible to student investigators during the Phase I site visit and interview process. Subsequently, he used the ArcGIS Spatial Analyst Extension to model potential subsurface contaminant migration in the event of a release into the BA simulation environment. In this way, Sperone was able identify potential areas for Phase II ESA recommendations and demonstrate the utility of GIS tools to perform analyses and prepare professional materials for communicating project results.

Feedback from our students has indicated that the authentic, realistic nature of the BA simulation greatly enhanced their ability to understand and apply the relevant ASTM standards. One student wrote: "I thought the BA simulation was invaluable to students. The Phase I ESA knowledge gained from reading through the standard is reinforced with the game. It puts a practical twist on a document that can be difficult to focus on (hooray for legal jargon!). The experience will greatly aid students heading into consulting/government jobs."

Angelo Lampousis, *City University of New York*

The Brownfield Action simulation and curriculum has been used at two different colleges of the City University of New York (CUNY). In both cases BA was adopted at the undergraduate and graduate levels of the course "Phase II Environmental Site Assessments" (City College of New York EAS 31402 [undergraduate] and EAS B9235 [graduate], Hunter College GEOG 383 [undergraduate] and GEOG 705 [graduate]). The combined number of students introduced to the BA simulation to date is 24. The academic background of the students involved ranged from geology, environmental sciences, and geography, to urban planning and sustainability.

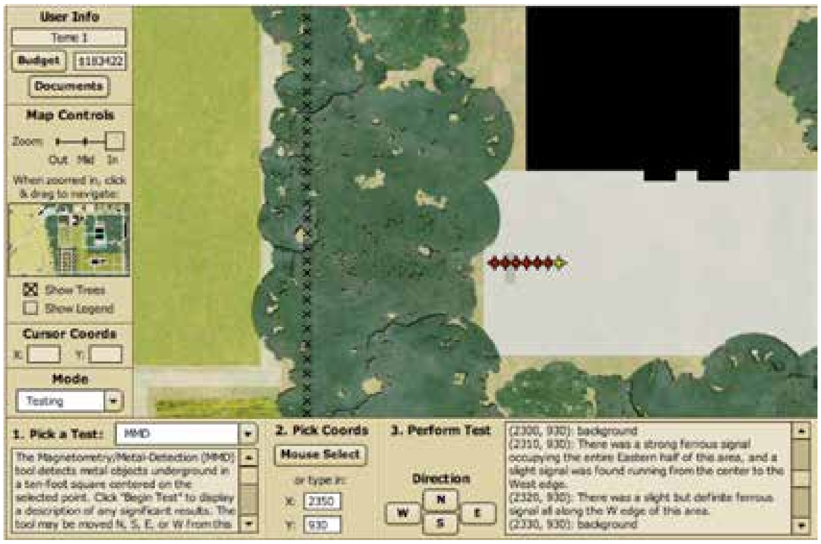
The BA simulation was used as a refresher for the Phase I process, since most students had already completed the Phase I environmental site assessment course that is also a prerequisite for the Phase II course. The BA simulation served this purpose exceptionally well. Students had the opportunity to experience and practice a realistic interview component of writing Phase I reports as they interacted with the characters of the simulation. This addressed a specific gap in the CUNY curriculum that, while strong in using real data on real estate properties located in New York City (Lampousis 2012), treated interviews as a data gap (i.e., per ASTM designation E1527 – 05) due to legal and other restrictions on allowing college students to interact with property owners in an unsupervised manner. The BA simulation addresses this gap through its incorporation of a wide range of very thoughtful fictional interviews. The BA simulation experience for CUNY students was realized through several homework assignments culminating in a Phase I report. Due to time constraints, considerable amounts of information from the simulation, including data for topography, depth to bedrock, and depth to water table, were made available to CUNY students from the very beginning. Students were also assisted by the instructor in their construction of a conceptual site model.

Overall, the adoption of the BA simulation within the two CUNY colleges greatly reinforced student learning on the topic of environmental site assessments. The BA simulation provided an opportunity to test the knowledge and level of students' understanding achieved up to that point. Students were able to get a panoramic view of the process, from signing the initial contract to submitting a final report. Because everything they did in the simulation cost them money, they also experienced working within a budget. The BA simulation will be used in the future starting in the Phase I course offered in the fall, and there are plans to adapt the BA simulation for a geographic information systems platform in the "Introduction to GIS" scheduled for the spring semester 2014. The latter will be in collaboration with Gianluca Sperone of Wayne State University.

Saugata Datta, *Kansas State University*

Brownfield Action has been used at Kansas State University (KSU) since 2009 for the undergraduate and graduate students in the lecture and laboratory courses of Hydrogeology (GEOL 611, with an average of 20 students mainly from the geology, biology, agricultural and civil engineering departments), Introduction to Geochemistry (GEOL 605/705, 10 students, mainly from the geology, agronomy, and chemistry departments), and Water Resources Geochemistry (GEOL 711, eight students from veterinary medicine, geology, and agronomy). All three have been offered as interdisciplinary courses.

In Hydrogeology, BA is utilized as the foundation for a one-month practicum. Students work in teams of three and are given complete access to the BA simulation and website including all data and documents. Student teams must choose a topic or specific problem to be solved within the BA simulation. Topics range from using the BA simulation and database for a Phase I ESA of the Self-Lume property or the BTEX Gas Station, for flow net exercises to delineate various contaminant plumes (gasoline or tritium), for simple permeameter measurements to understand hydraulic conductivity, or for utilizing the many soil exploration tools (drilling, seismic reflection and refraction, ground penetrating radar, soil gas) to determine plume location and its migration paths, and chemical characteristics of different contaminants. Lectures are developed based on the topics chosen. Each team is required to write a report on their findings and evaluate what they have learned from their practical experience with the simulation. Poster sessions have often been assigned so that students may share their experiences using the BA simulation with other students to demonstrate how different methods and principles are used to solve complex



The Magnetometry/Metal-Detection (MMD) tool detects metal objects underground in a ten-foot square centered on the selected point. Click "Begin Test" to display a description of any significant results. The tool may be moved N, S, E, or W from the

(2300, 930): background
(2310, 930): There was a strong ferrous signal occupying the entire Eastern half of this area, and a slight signal was found running from the center to the West edge.
(2320, 930): There was a slight but definite ferrous signal all along the W edge of this area.
(2330, 930): background

FIGURE 7. The Brownfield Action "playing field" in Testing Mode with zoom function applied and magnetometry/metal detection measurements being made.

hydrological problems. Additional faculty members are invited to these poster presentations and interact with and question the student teams.

In Geochemistry, BA is used for one month as a case study as part of the final project. Students use BA in order to understand the chemical characteristics of organic contaminants, the chemistry of groundwater, and the use of various field or laboratory geochemical analytical tools to measure various contaminants, map these contaminants in the surficial soil cover, and create hydrochemical maps with piper diagrams for various inorganic contaminants. Students learn how different plumes will mix or impact each other. BA allows students to develop a clear understanding of the composition of different contaminants and their MCLs in the environment.

In Water Resources Geochemistry, BA has been used in collaboration with other users of BA from Lafayette College (LC) and Wayne State University (WSU). Students are assigned to investigate BA in order to write Phase I and II ESA reports. There are invited lectures from within KSU as well as video lectures transmitted by instructors from LC and WSU. Students from KSU present their findings to students in an Environmental Engineering course at LC and a geology course at WSU, who in turn present their findings to the KSU students. Working with instructors from WSU, students at KSU learn how to use ARC GIS on the BA database. The topics in this video conferenced course evolved from the joint use of MODFLOW and Groundwater Modeling Systems (EMS-i) in tracing groundwater contaminants in the BA aquifer.

Typical student comments about the use of BA include: "One of the greatest ways to connect to a real world problem and it was interesting how we were acting as consultants, and tried not to leak ideas to the other groups," and, "I learnt more about the application of Darcy's law when I was taught with BA, even the water table characteristics, and the direction of groundwater flow were more clear when BA was demonstrated to us." Students also commented on how they learned to work as a consultant and that one cannot make mistakes that might result in losing the contract or not making a profit. Several students have gone to job interviews and used BA to demonstrate their knowledge of ESAs and to respond to questions from the interviewers. BA played a significant role in the hiring of these students by government agencies and has also led to a dialogue with these agencies on how to use BA within communities they serve that are affected by brownfields.

Arthur D. Kney, *Lafayette College*

Over the last seven years the Civil and Environmental Engineering (CE) program at Lafayette College has used Brownfield Action successfully in two courses: Environmental Engineering and Science (CE 321) and Environmental Site Assessment (CE 422). CE 321 is an introductory course, and BA is used to introduce the issues of brownfields, remediation, and environmental regulations. CE 422 is a course in which students learn how to do Phase I Environmental Site Assessments (ESAs) consistent with ASTM 1527. Because most of the fundamental science needed to understand and participate in the BA scenario is taught to CE students throughout their first few years of our CE program, use of BA in CE 321 and 422 is targeted at applying their accumulated fundamental skills and knowledge in a realistic simulation in addition to teaching the details of the ESA process. Following a two-week exercise utilizing BA, students are prepared to do a real-time site assessment on neighboring properties.

My experience has shown that BA is very applicable to the field of civil engineering from initial investigation through remediation and that the interdisciplinary, realistic nature of BA provides an effective tool with which to teach aspiring civil and environmental engineers. Connections to the practice of civil engineering are played out in numerous scenarios in BA. For example, understanding how chemicals move through the water and soil is made evident through models that civil engineers are taught in water quality and water resource classes. Methods and practices used in remediation are common themes taught in upper level environmental engineering courses. Additionally, ESAs must be accomplished by an "Environmental Professional" as outlined in the US CFR 40:312.21. BA provides a wonderful storyline linked to believable data that ties together individuals and their community with industry and very real economic and environmental concerns. In order to piece together the truth, critical thinking skills must be used to interpret and communicate the significance of data obtained from the simulation.

In CE 422 especially, the incorporation of BA has tremendously improved student understanding of the ESA process as compared to classes taught prior to use of BA. Anecdotal evidence from student conversations, faculty observations, student test scores, and the fact that BA continues to be a central part of CE 422 all support this statement. Beyond CE 321 and 422, students have reported that BA has strengthened their ESA skills in senior-level design projects and has provided evidence of competence when applying for jobs. In fact, it is not uncommon to hear that students have not only gotten jobs because of their ESA skills but have also gone on to perform ESAs in their jobs. Because of these reports from students, future plans include introducing some form of an ESA course for engineering professionals. Incorporating BA would be integral, because of the fact that one can quickly comprehend the overall ESA process through the interactive, informative framework of the simulation.

As part of the collaborative network, Saugata Datta from Kansas State University (see above) and I have used BA to complement several courses. Our most recent course development is a team-taught course module between Kansas State and Lafayette. Graduate and undergraduates from both institutions have worked together reconstructing plume flow via groundwater models like MODFLOW and Groundwater Modeling System (EMS-i), using data from the BA simulation. Students connect the groundwater solution to the models in the existing BA simulation and make the BA narrative come alive as they learn how the various chemical and kinetics principles of contaminants behave throughout the BA storyline. In addition, other collaborative engagements have blossomed through BA team interactions, such as a recent set of academic video discussions between Wayne State University, Kansas State University, and Lafayette College students and faculty revolving around the overuse of key nutrients, phosphorous and nitrogen. Consistent with professional practice, future plans include developing a workshop open to environmental professionals interested in learning how to conduct ESAs. BA would be used to help professionals connect to the task at hand just as it has been used in CE 422.

Discussion

Assessing the Effectiveness of the Brownfield Action Simulation

All faculty using BA in their courses report high levels of student engagement with the simulation and increased confidence in students' ability to understand and apply science to solve problems. Although a simulation, BA is grounded in civil, legal, and scientific reality such that experience gained through BA is directly applicable to the real world. This is demonstrated by the many students who report that BA has assisted them in gaining employment as environmental professionals. Other important professional and conceptual skills reported being taught and learned in the context of the BA simulation include data visualization, map-making, budgeting, formal report writing, making formal oral presentations, as well as decision-making, dealing with ambiguity, teamwork, and networking in information gathering.

Reliable summative assessment of the pedagogical effectiveness of the BA simulation has not yet been performed due to the lack of appropriate control groups (the courses discussed above are not taught in multiple sections with some instructors using BA and some not) and a lack of appropriate data on student performance prior to the adoption of BA in courses. However, a variety of formative assessments of the BA simulation were incorporated throughout the design and initial use of BA at Barnard College to provide feedback and confirmation of the effectiveness of the simulation (Bower et al. 2011). We are currently developing and testing a survey-based formative assessment utilizing the SENCER SALG tool available online (http://www.sencer.net/assessment/sencersalg.cfm). A SENCER SALG instrument consists of a pre- and post-course survey taken online that provides instructors with useful, formative feedback for improving their teaching. A SALG instrument provides a snapshot of student skills and attitudes at the start and end of courses, allowing instructors to gauge the effectiveness of teaching strategies, methods, and activities such as the BA simulation (Seymour et al. 2000). A preliminary version of a SALG instrument designed to measure student learning gains resulting from working with the BA simulation has recently been deployed by Bret Bennington and analysis of the results show marked gains from the beginning to the end of the semester (see discussion above). At the next meeting of BA users in the spring of 2014 we will finalize this SALG instrument and begin deploying versions of it to measure the impact of BA on student learning in a variety of educational settings and applications.

Ongoing Work and Future Directions

The tenth in a series of seminars and training sessions for Brownfield Action will be held at Barnard College in April of 2014. Most of the early seminars were devoted to training new users of the simulation and to troubleshooting problems existing users were having. As the simulation evolved, two new versions of BA were produced making the simulation web-based, enhancing the features of the "playing field," and developing a "modularized" version that is more adaptable to creative new uses. While new users are still being trained, the ninth seminar held in the spring of 2013 was devoted primarily to the sharing of experiences teaching with BA and presenting new applications of BA developed by current users. These included using the data in the BA simulation to teach modeling and analysis using GIS, using the simulation to teach undergraduates about Phase I Environmental Site Assessments incorporating GIS, the use of the gasoline contaminant plume in the simulation as the basis for a six-week unit on toxins and environmental site investigations for high school students, the creation of evaluation tools for the assessment of the effectiveness of BA in an undergraduate hydrogeology course, the modeling of groundwater contaminant plumes from the BA database as part of graduate level student exercises, and discussion of new possibilities for furthering the BA simulation using 3-D gaming technologies.

It is apparent from the above reports that users continue to develop new ways of using BA to teach science in the context of civic engagement. While BA was not developed to teach GIS, the work done in this area suggests that the BA simulation can be easily adapted to enhance GIS instruction. The data- and context-rich virtual world of BA provides an ideal tool for realizing SENCER goals for teaching science through important civic issues and motivating students to learn and understand basic science. Environmental contamination and brownfields are universal problems in today's world and incorporate civic issues to which every student can relate. BA provides a virtual world and narrative in which students figure out for themselves how to apply basic scientific concepts learned in a course to solve real, practical problems. There is significant potential for further growth of the community of BA users but it is also apparent that BA must undergo significant technological change to bring it up to date with new advances in online delivery and learning technology. A "next-generation" Brownfield Action project is in the early stages of development in order to create a more interactive, 3-D game-based learning environment for the simulation. We would also like to add new data to the simulation, expanding the range of environmental toxins represented to include dense non-aqueous phase liquids (DNAPLS) and nitrates, two major sources of groundwater contamination. Developing the next generation of BA will require funding, and appropriate documentation of learning gains will be needed to make a case for continued investment in BA. To this end we are currently developing standardized student assessment tools using the SENCER SALG that will be deployed across the community of BA adopters. But most importantly, improvement of the Brownfield Action simulation will be facilitated through expansion of the community of instructors who use BA in their courses and who will continue to develop innovative approaches that can be shared across the BA collaborative network.

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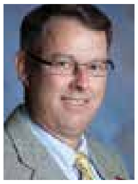

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Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process—ASTM Designation E1527 – 05

Standard Practice for Environmental Site Assessments: Phase II Environmental Site Assessment Process—ASTM Designation E1903 – 11

PROJECT
REPORT

Vanishing Fireflies: A Citizen-Science Project Promoting Scientific Inquiry and Environmental Stewardship

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Abstract

Fireflies are a unique part of the natural landscape. Urban development and changes in forestry practices have altered the landscape, causing a decline in firefly distribution and abundance. Assessment of firefly abundance through counts of bioluminescence flashes provides an environmental quality indicator that can be easily observed and quantified by citizen scientists. Researchers at Clemson University, collaborating with resources managers, educators, and teachers from local non-profit organizations and schools, have conducted firefly surveys in the state of South Carolina (SC) since 2010. This community-based project begins with the incorporation of scientific inquiry into service-learning to promote sustainability and ultimately environmental stewardship. This paper describes project activities and summarizes the results and observations of the four-year-old program. Lessons learned from this project can be applied to citizen-science projects in other regions to monitor different organisms such as cicadas, dragonflies, and frogs.

Introduction

Citizen-science projects call on individuals to gather data for use by scientists to investigate research questions (Bonney et al. 2009). While these projects can produce large databases, it is possible that their benefits extend further (Trumbull et al. 2000). By engaging citizens in authentic science, some argue that these projects can have an impact on participants' understanding of science content, understanding of the process of science, and attitudes toward science and the environment (Cohn 2008). Although citizen-science projects are growing in popularity, there is little published evidence on the impacts of such projects on the participants (Druschke and Seltzer 2012).

Fireflies (*Coleoptera: Lampyridae*), sometimes called lightning bugs, produce bioluminescence to attract mates or even prey (Barrows et al. 2008; Viviani et al. 2010), and they can be easily observed during the spring and summer (Frick-Ruppert and Rosen 2008; Lloyd 1972). Citizens of all ages exhibit an interest in, and have fond memories of, observing these amazing insects (Ho et al. 2009). Many adult citizens have inquired about the recent rarity of firefly flashes, which are perceived as having been ubiquitous in their childhood. Such interest has provided environmental science educators an opportunity to use fireflies as a charismatic and easily observed educational tool (Faust 2004).

Environmental indicators are used to communicate information about the health of ecosystems and the impacts of human activity to school children, the general public, and government policy makers (Turcu 2013; Conway et al. 2009). These indicators can reflect biological, chemical, and physical aspects of ecosystem health. Fireflies are reliable indicators of environmental health because their abundance is correlated with the availability of healthy habitats (Kazama et al. 2007; Takeda et al. 2006). The habitat of fireflies can be significantly impacted by changes in land use patterns and structures, such as converting forested areas into open lawns, residential gardens, and agricultural fields (Kazama et al. 2007; Jusoh et al. 2010). Indiscriminate use of insecticides in lawns and urban areas can kill many non-target insects, including fireflies. Pollution from commonly used chemicals (e.g., pesticides and fertilizer) and biological pollutants (e.g., pet waste) can also alter the quality of the habitat (Lee et al. 2008; Leong et al. 2007). Strong, bright artificial light can outshine firefly flashes and interfere with mating behavior (Viviani et al. 2010). All these factors work in concert to reduce the quantity and quality of habitat, thus reducing the abundance of fireflies.

Forested land makes up 66 percent of South Carolina's total land area (Conner 1993) and fireflies are commonly observed in the natural areas (Barrows et al. 2008; Frick-Ruppert and Rosen 2008). South Carolina, similar to many states in the U.S.A. and many parts of the world, has experienced significant population and economic growth, which has resulted in a significant loss of natural habitats. For instance, urban areas surrounding the city of Charleston have increased sevenfold in the last 40 years, from 180 km2 in 1973 to 1,300 km2 in 2010, and they are expected to increase to 2,250 km2 by 2030 (Allen and Lu 2003). The population of several coastal counties in South Carolina is approaching one million, a 25 percent increase in the last decade (US Census Bureau 2010). Commercial and residential development and resultant land-use changes undoubtedly modify the landscape and alter the environmental quality of coastal areas (Pouyat et al. 2007). To protect the natural environments in South Carolina while providing for economic growth, sustainability and environmental stewardship have become important concerns to local communities.

The combination of civic concerns and the value of fireflies as an educational tool led to the development of Clemson University's Vanishing Firefly Project in 2010. Firefly surveys have been promoted worldwide as citizen-science projects (Ho et al. 2009; Masaki 2011). The Clemson Vanishing Firefly Project has four primary project goals: (1) Science Inquiry—Engage citizens in scientific practices to understand the impacts of urbanization on environmental quality; (2) Service-Learning—Increase the skill of citizens in making critical, scientific, and informed decisions through community and service activities; (3) Sustainability—Protect natural habitats through effective land and resource management practices; (4) Stewardship—Provide opportunities for citizens to participate in environmental and sustainability studies and activities. This paper summarizes activities carried out since 2010, the impacts on participant understanding of scientific inquiry and attitudes toward science and the environment, and the difficulties encountered during the organization of the project.

Project Activities

The Clemson Vanishing Firefly Project, which began in 2010, is a collaborative effort by researchers from Clemson University, land and resource managers from Hobcaw Barony Nature Reserve, educators from Hobcaw Barony Discovery Center, teachers from local schools, and leaders of local nonprofit organizations. Researchers from Clemson University focus on research about environmental quality and firefly biology and lead the field investigations and data analysis. Land and resource managers manage the 12 study sites in Hobcaw Barony and provide historical and geographic information on the study sites. Teachers and educators serve as mentors to the students and other participants during the service-learning experience. The Hobcaw Barony Discovery Center and Baruch Institute of Coastal Ecology and Forest Science provide long-term opportunities to participants who are interested in continuing the research and who volunteer to work at the Hobcaw Barony. All parties work together in promoting and advertising the Clemson Vanishing Firefly Project to local communities.

The Clemson Vanishing Firefly Project was composed of two service-learning activities each year: (1) a Firefly Field Day and (2) a South Carolina Statewide Firefly Survey. Both activities occurred in May or early June during the peak season

FIGURE 1. Aerial view of the 12 study sites at Hobcaw Barony, Georgetown, SC. (1) Managed forest burned in 2009; (2) Natural forest; (3) Clear-cut recovery area; (4) Managed forest; (5) Salt marsh; (6) Hurricane damage recovery area; (7) Active logging area; (8) Natural forest; (9) Natural forest; (10) Open and abandoned housing area; (11) Forest thinning area; and (12) Low density housing area

of firefly activity in coastal South Carolina. The Firefly Field Day was conducted at Hobcaw Barony, a 17,500-acre wildlife refuge and a member of the National Estuarine Research Reserve System. Twelve sites on Hobcaw Barony representing different land uses and forest management practices were selected as survey sites during the Firefly Field Day (Figure 1). Activities during the field day included a half-day program that included a one-hour orientation with classroom instruction, a two-hour daytime field survey and sample collection, and a two-hour nighttime firefly abundance assessment. During the orientation and classroom instruction, experts in entomology, forestry, and soil science provided some brief background information on firefly biology, methods for firefly counting and identification, methods for soil and litter sampling, general field safety, environmental impacts from coastal developments, and importance of sustainability.

The objective of the daytime survey was to provide hands-on experiences to participants about the methodology and principles of environmental and forest research. All participants were asked to inspect all 12 survey sites. They learned about the impacts of forest management practices, land use patterns, and natural disasters (e.g., hurricanes) on vegetation and the soil carbon cycle in forests. In addition, they participated in a soil carbon study (Figure 2) by collecting soil and litter samples in three selected field sites (sites 1, 4, and 9 listed in Figure 1), representing burned, actively managed, and natural forests. This exercise, which required participants to measure and interpret their data, illustrates the amount of anthropogenic disturbance in each forest ecosystem (Dale et al. 2002). The nighttime survey was intended to assess firefly abundance and provided a unique opportunity for the participants to learn first-hand the biology and ecology of fireflies in the field, as well as to observe the amazing bioluminescence display of fireflies. Participants revisited the 12 field sites after dark in vans provided and driven by staff of the Hobcaw Barony Discovery Center and Clemson University. A data sheet was given to each participant for recording his/her observations. At each site, the participants were then asked to count the number of fireflies in front of their windows within a one-minute period. The participants were also asked to identify the firefly species based on flashing patterns, as discussed in the classroom instruction, when they were able to do so. At the end of the survey, researchers collected all data sheets and summarized the results at a debriefing session.

Participants of the South Carolina Statewide Firefly Survey were asked to collect data on firefly abundance observed on one night in May or early June and submit their observations through the project's web page. The method of collecting the data was similar to the one used in the Firefly Field Day—each participant counted the number of fireflies across his/her field of vision within a one-minute period. Background information, study objectives, and a detailed sampling procedure were posted on the web page. The web page also included pre-set options for land use selection, which included farm, forest, home lawn and garden, marsh edge, wood-bordering lawn and garden, and other. The result of the statewide survey, presented as GIS–marked locations on a map, was posted on the Vanishing Firefly Project web page and disseminated to local newspapers.

In 2013, the field day and statewide survey were both conducted on June 1. In addition to the field day, researchers conducted several one- to two-hour workshops with school and community groups. Participants for the statewide survey were recruited through local and statewide media, and their ages ranged from eight to 76 years of age. While more than 1,000 participants uploaded firefly count data to our website or through our smartphone app, the findings reported in this paper focus on the 26 participants who attended either

FIGURE 2. The two high school students on the right worked with two senior participants on litter collections during a daytime survey

a workshop or the field day prior to their participation in the firefly field survey.

Participants attended workshops sometime during the month prior to the day of the firefly field survey date. Workshop attendees were asked to complete an initial questionnaire. The questionnaire asked for demographic information and the participant's knowledge of firefly biology, understanding of the process of science, and attitudes toward science and the environment. During the workshop, participants engaged in discussion and activities related to firefly biology, methods for firefly counting and identification, methods for soil and litter sampling, general field safety, environmental impacts from coastal developments, and the importance of sustainability. Following their firefly field survey, participants were asked to complete a second questionnaire online. Many of the items on this questionnaire were identical to items on the first one.

Project Findings

Data collection and analysis by the Clemson Vanishing Firefly Project are ongoing; therefore, we do not report the results of firefly counts in this paper. In brief, firefly abundance assessments during the Firefly Field Day suggest at least three *Photinus* species were observed at Hobcaw Barony. Results also indicate high between-year and between-site variations in firefly abundance at the 12 sites. Data from the South Carolina Statewide Firefly Survey suggest great differences in firefly abundance among locations and land use pattern, even within a single city. The observation that certain urban parks or reserves provide refuge and habitats for the firefly populations is an encouraging sign in the conservation of these insects. In the 2011 South Carolina Statewide survey, 42 percent of participants observed no fireflies, 32 percent reported one to 10, 14 percent reported 11 to 49, and 12 percent observed more than 50 fireflies in a minute. Most of the participants chose lawn and garden land use patterns, indicating that most participants reside in urban or suburban environments.

Questionnaire responses indicated some changes in understanding of the process of science from before the workshop to after the firefly field survey (Table 1). While participants agreed that the scientific method is used in all research studies, they better understood that there is no single correct approach to scientific research. They better understood that scientists have their own biases and perceptions, and also that those scientific ideas can be changed.

Participants also responded to several open-ended questions about the process of science, such as "What does it mean to study something scientifically?" A 1–7 scoring scheme was used to code responses on the degree of scientific literacy (Brossard et al. 2006). The scores on both the initial and the final questionnaires showed that most of the participants' responses described hypothesis testing, use of controls, and conclusions based on data.

Questionnaire responses indicated that participant attitudes toward science and the environment changed little as a result of the firefly field survey (Table 2). However, there were significant differences in responses to the item "Humans have a large impact on their environment," and differences approached significance on the item focused on participant interest in protecting the environment.

While surveys of fireflies and participants have been informative, there have been other lessons learned as a result of this project. The firefly counts used in data analysis could be higher than actual observations. There is always doubt concerning the reliability and repeatability of data collected by volunteers (Cheung and Chow 2011; Fogleman and Curran 2008). Despite the introduction and training, firefly identification using flash patterns was difficult for most participants. Double counting of the same firefly was the most common problem for non-experienced participants, since fireflies move around while flashing. It is difficult to track its flying path in the dark, particularly in areas with large numbers of fireflies. Based on the individual recording sheets, participants sometimes recorded higher numbers than the technical staff, and

TABLE 1. Results of questionnaire measuring participant understanding of the process of science

LIKERT ITEM	INITIAL QUESTIONNAIRE MEAN (SD)	FINAL QUESTIONNAIRE MEAN (SD)	P VALUE
The scientific method is used in all scientific research studies.	3.6 (1.2)	3.5 (1.1)	0.74
No experiment can fail if the scientific method is followed.	2.6 (1.1)	2.1 (0.9)	0.01*
Conducting an experiment is difficult.	2.9 (1.0)	2.9 (1.1)	0.84
The results of an experiment will be the same each time it is conducted.	2.2 (0.9)	1.9 (0.5)	0.03*
Once a study is completed, the answer to the research question will be known.	2.4 (1.0)	2.1 (0.6)	0.13
Scientists stay objective as they work.	3.6 (0.9)	3.1 (0.8)	0.04*
Scientific ideas can be changed.	4.0 (1.0)	4.3 (0.5)	0.05*
I only counted a few fireflies so the data are not useful.	1.7 (0.9)	1.5 (0.5)	0.26

An (*) asterisk indicates a statistically significant difference.

younger students recorded higher numbers than adults. Unfortunately, the number of participants in each group (i.e., technical staff, adults, and students) was too small to statistically verify these observations.

Students and adults appeared to have different attitudes towards this service-learning exercise. Students were primarily interested in field activities such as firefly counts and vegetation and soil sample collection and less interested in the introduction and group discussions. In contrast, adults expressed strong interest during the introduction in understanding the causes of firefly occurrence and disappearance. Despite the differences in behavior, both groups were excited and enjoyed the experience of observing fireflies during the nighttime surveys.

Conclusions and Implications

The findings indicate that the project had a small impact on participants' understanding of the process of science. There were significant differences on several of the Likert items addressing the nature of science from initial to final administration. The initial to final comparison for the items related to attitudes toward science and the environment showed almost no differences. It is possible that citizens interested in a workshop and field survey related to fireflies already have an interest in science and protecting the environment. Our future directions include encouraging participation for school-aged citizens as well as having participants engage with the project for a longer period of time. In order to impact the citizens who participate in the project, citizen-science projects should encourage collaboration with scientists versus merely collecting data for scientists. In order for participants to feel like collaborators, this project will begin to encourage all participants (whether on-site during a field day or off-site doing the statewide survey) to participate in long-term data collection for two to four weeks. At the end of the data collection period, participants will be invited back (either in person or online) to view a visualization of the long-term firefly count data as well as other data such as land use

TABLE 2. Results of questionnaire measuring attitudes toward science and the environment.

LIKERT ITEM	INITIAL QUESTIONNAIRE MEAN (SD)	FINAL QUESTIONNAIRE MEAN (SD)	P VALUE
Decisions about the environment should be made based on science.	4.0 (0.8)	3.8 (1.0)	0.13
Science is useful for solving problems of everyday life.	4.4 (0.6)	4.4 (0.7)	0.60
I am interested in science.	4.4 (0.8)	4.5 (0.7)	0.80
Science can make our lives healthier, easier, and more comfortable.	4.4 (0.6)	4.2 (0.7)	0.13
I usually understand what I read and hear about science.	3.9 (0.7)	4.0 (0.7)	0.58
I enjoy talking to other people about science.	4.0 (1.0)	4.1 (0.7)	0.54
It is not important to know science to get a good job.	2.5 (1.0)	2.3 (0.9)	0.48
I am interested in protecting our environment.	4.4 (0.7)	4.6 (0.5)	0.07
Humans have a large impact on their environment.	4.2 (0.7)	4.8 (0.5)	0.01*
It is important for me to share my views on the environment with others.	3.9 (0.8)	3.9 (0.9)	0.91

An (*) asterisk indicates a statistically significant difference.

patterns, soil and litter quality, and other environmental indicators. Participants in the callback meeting at Hobcaw Barony will participate in a discussion of the results, while participants online will be asked to consider questions intended to guide their thinking about the results. Being more engaged in the project and contributing more to data collection and discussion of the results might lead to more gains in content knowledge, understanding of science processes, and attitudes toward science and the environment.

The Vanishing Firefly Project is in the final stages of integrating mobile device technology. Participants attending the Firefly Field Day will begin collecting data using a newly developed mobile phone app to record the distribution and abundance of fireflies. This mobile phone app will make data collection more efficient and will encourage the general public to participate (Teacher et al. 2013; Johnson and Johnson 2013).

While our preliminary results on the impact of the project on participants are encouraging, we need to develop a more rigorous data collection plan. Specifically, we want to investigate the impact the project has on the participants' knowledge of fireflies, their understanding of the process of science, their attitudes toward science and scientists, and their attitudes toward the environment and conservation. After their participation in the project, a long-term post-activity survey will also gauge participants' engagement in community service, participation in sustainability and environmental stewardship activities, scientific literacy, and career goals (depending on their age). Through surveys, field observations, and interviews we will have a better understanding of the benefits and limitations of citizen-scientist programs.

Our initial comparison revealed that firefly abundance data collected by participants were different from those collected by experts. There are two ways to address this issue. First, the participants need more training in the method of assessing firefly abundance and identification. Web-based simulations have been successful in other citizen-science projects (Mulder et al. 2010). We will develop online simulations of firefly flashing patterns to better train our participants in identification. We will also develop different field days or training modules that are more suited to the different learning behaviors of adults and children.

The Clemson Vanishing Firefly Project is a citizen-science project that begins with scientific inquiry incorporated into service-learning to promote sustainability and ultimately environmental stewardship. The Clemson Vanishing Firefly Project provides an opportunity for citizen scientists of all ages to answer an important *science inquiry* question—Are the fireflies disappearing?—through volunteerism, training, and collection of scientific data *(service-learning)*. The goal of the Clemson Vanishing Firefly Project is to educate and prepare citizens to integrate *sustainability* and environmental *stewardship* into their future activities. In addition, this service-learning experience may motivate young participants to improve their scientific literacy and may encourage enrollment in post-secondary science programs and possibly even a career in environmental sciences. Since 2010, the project has engaged over 1,200 citizens in its annual Firefly Field Day and South Carolina Statewide Firefly Survey. The participants have received in-person or online training and information on firefly biology, environmental science, scientific methodology, and environmental sustainability. The soil characteristic survey and firefly abundance assessment have given participants hands-on experience in scientific research. The participants have collected valuable data; however, a more rigorous training program must be developed to increase the reliability of abundance and identification data from the participants. Adults and children have different behavior and attitudes toward the original program; therefore, different programs aimed at different age groups will be developed. A long-term survey will be developed to accurately assess the engagement of the participants in sustainability- and stewardship-related activities. If the Clemson Vanishing Firefly Project is successful in educating and engaging the citizens of South Carolina using the charismatic firefly, we hope it will lead to the integration of environmental sustainability and stewardship into the activities and the decision-making process of local communities.

Acknowledgments

This research is also based on work supported by a USEPA P3 Project grant under project number SU835496 and by a NIFA/USDA grant under project number SC-1700409 and 1700473. The authors would like to thank the Hobcaw Barony and all citizen scientists for their support. Technical Contribution no. 6220 of the Clemson University Experimental Station.

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PROJECT
REPORT

Staying SMArT:

Introduction, Reflection, and Assessment of an Inquiry-based Afterschool Science Program for Elementary School Students

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Abstract

Our public schools need more STEM infusion. Simultaneously, civic engagement in higher education opens a window for colleges to partner with local communities to inject science into affordable afterschool programs. We offer a description, reflection and preliminary assessment of an enrichment program, "SMArTeams" at Southwestern University (Georgetown, Texas). Using a pre/post-test design, our study demonstrated that elementary school students exhibited gains in confidence, experimental design, curiosity and science enjoyment in ten weeks. Surprisingly, they did not show similar gains in drawing conclusions or imagining future STEM careers. However, extending beyond survey results, reflections of SMArTeams' Day Coordinators confirmed that young students successfully presented projects and responded positively when asked about future endeavors. Our assessment identified the need for increased discussion of STEM career pathways to broaden perspectives of elementary school students. Overall, we present SMArT as a cost-effective, engaging outreach program for creating partnerships between colleges and local school districts.

Introduction

Despite increased efforts, the U.S. struggles to achieve proficiency in science, math, engineering, and mathematics (STEM) education and related careers. According to the 2011 National Assessment of Educational Progress Exam, thirty-five percent of eighth graders scored below "basic" on science, and twenty-seven percent scored below "basic" on math

(NAEP 2011). Of the students who scored at least "basic" in science and math, the majority did not score above "basic" proficiency (NAEP 2011). According to the 2009 Program for International Student Assessment, the U.S. fluctuates from nineteenth to twenty-sixth place (out of sixty-five countries) in science, and between twenty-sixth and thirty-sixth place in math (PISA 2009). Such rankings prompt the need to examine where and how elementary school students can make a strong start in science and math.

To encourage other universities and colleges to establish a SMArT (Science and Math Achiever Teams, hereafter "SMArT") program, we offer an in-depth look at SMArT at Southwestern University (SU), a small liberal arts college in Georgetown, Texas, with approximately fifteen hundred undergraduate students. With the elementary students traveling to Southwestern for the activity, SMArT operates as a once-a-week afterschool program for third through fifth graders. Students engage in STEM education through individual implementation of the scientific method with the guidance of an undergraduate mentor. Student-mentor pairs complete a project chosen by the student over the course of nine to ten weeks and give a poster presentation at the program's conclusion.

From Spring 2007–Spring 2011 (i.e. time of this program assessment), SMArT served approximately one hundred and five students, working with ten to twelve students each semester and in one semester running two teams simultaneously. Since 2011, the SMArT program has continued these enrollment practices and just concluded its 14th semester in Spring of 2013 (> 150 students). Participating elementary schools thus far include Rae McCoy Elementary, Dell Pickett Elementary, Everett L. Williams Elementary, Patricia Webb Cooper Elementary, Joann Ford Elementary, James E. Mitchell Elementary, and Village Elementary, all within the Georgetown Independent School District (Texas).

While we hypothesize and have anecdotally observed STEM education, we sought an additional objective and qualitative assessment of SMArT's ninth iteration. The assessment analyzed the program's routine curriculum and practices to 1) measure the success of SMArT's core objectives; 2) improve the program; and 3) present a science-based civic engagement program model for other institutions of higher learning. Our assessment included problem solving prompts, surveys, and interviews before and after the program to measure student outcomes and identify areas of improvement.

Background

Within the public educational system, many teachers face three main struggles: (1) the pressure to "teach to the test" for state assessments (Jehlen 2009), (2) the difficulty in moving beyond lecture-classroom methods (NAEP 2011), and (3) being personally uncomfortable in teaching math (Epstein and Miller 2011). The average hours per week spent teaching core science in elementary schools dropped from three hours in 1993–1994 to only two and a third hours in 2007–2008 (United States Department of Education 2008). With its focus on test-based learning, the education system has reduced the importance of basic science with the loss of exploration and inquiry-based learning opportunities.

Afterschool programs provide a good vehicle for enrichment and additional educational benefits not found during normal school hours. For example, inquiry-based STEM projects, activities, and experiments can be performed during afterschool programs without the constraints of traditional school schedules. Additionally, children who regularly attend quality afterschool programs usually do better in school and have fewer behavioral problems (Durlak et al. 2010). Therefore, if conducted properly, afterschool programs can be used as an outlet for increasing educational enrichment.

Despite the documented benefits of structured and enriching afterschool programming, an enormous need exists. Although 8.4 million or fifteen percent of children in grades kindergarten through high school (K-12) are enrolled in afterschool programs, 18.5 million more would enroll if local programs existed (Afterschool Alliance 2009). The great need for quality afterschool programs opens a window for universities to create affordable afterschool programs within local communities to enrich K-12 education, especially in the sciences. Often tied to the socioeconomic base of the taxpayers, funding for extracurricular or afterschool programs varies widely across school districts. Reciprocal community-university partnerships can offer modest resources to support local education in districts with limited funding.

Increasing resources and innovative STEM education via college-student led organizations may inspire grade-school students to join STEM programs. Teacher recruitment may also occur among the university student participants. Through college and donor sponsored programs like SMArT, school districts and colleges can partner to fill the gap between education and experience. The smaller age gap between grade-school students and college mentors provides more immediate role models for children disinterested in or disheartened by math and science. Currently, only nineteen percent of K-12 students take advantage of available STEM-related afterschool programs when they occur in their school districts (CTEq 2012). The lack of participation in STEM programs likely arises from the cultural bias that math-related subjects and sciences are difficult or impossible to comprehend (Epstein and Miller 2011).

Furthermore, lower-income students typically encounter fewer opportunities to participate in STEM programs and understandably tend to develop less of an interest in the sciences and related careers (Epstein and Miller 2011; Museus et al. 2011). During regular school hours, only thirty-two percent of low-income students reported that teachers possessed the necessary supplies to complete lab activities (NAEP 2011). Across all income levels, only fifty-six percent of students participate in hands-on science activities once or twice a week (NAEP 2011). However, students who participated in lab exercises scored fourteen percent higher on the National Assessment of Educational Progress in science, equivalent to one grade level better (NAEP 2011). It is apparent that afterschool programs can help narrow the gap in STEM *exposure*.

SMArTeams – History and Mission

Responding to the community's need for better STEM education, in an effort to bolster career interest in STEM fields, Southwestern University implemented the Science and Math Achiever Team program model (i.e. SMArT) in a partnership with Georgetown Independent School District (GISD). Even before educational outreach and civic engagement started to gain a strong foothold in higher education, the basic framework for SMArT was established at Yale University in the early 1990s with founder Rowan Lockwood (Burks, personal communication). We use the term civic engagement holistically to include a wide range of activities that develop a person's sense of public responsibility and encourage a desire to contribute to the common good (Jacoby 2009). SMArT seeks to provide an alternative to the negative perception of STEM by providing elementary school students an engaging, dynamic, and fun inquiry-based learning experience. SMArT brings the process of discovery and the scientific method to each participating elementary student in a personal, individual, non-competitive format. The program fuels children's innate scientific curiosity, which—although this is not the direct intention—could develop into an interest in STEM subjects and potential future STEM-related careers.

In partnership with the local public schools, SMArT allows children across socioeconomic backgrounds to participate in an extracurricular, individualized, interactive science program, giving many children from lower-income families an otherwise unlikely experience. The SMArT model relies on three positive factors identified by the ASHE Higher Education Report to promote STEM education success in racial and ethnic minorities: (1) providing early exposure to STEM careers; (2) increasing STEM interest; and (3) bolstering self-efficacy in STEM subjects (Museus et al. 2011). SMArT integrates these three factors into a one-on-one mentoring program between an undergraduate mentor and an elementary school student, where the pair pursues questions driven by the elementary student's interests. The program indirectly touches on STEM careers through casual discussion between mentors and students. SMArT excels at increasing STEM interest by encouraging the students to choose their individual projects based on personal interest, create a project design, and take ownership of their projects at the end of program project presentation session. The Achievement Party, where the students present their projects, remains an integral cornerstone of the program. It celebrates the students' increased scientific knowledge and project accomplishments, and bolsters their self-confidence in math and science.

Program Description

SMArT began at SU in the spring of 2007 and has fielded a "team" every semester since its inception. Backed by university support and a recent endowment (expenditures amount to approximately $1200/semester), SMArT offers free programming to third through fifth graders enrolled in the local school district's afterschool enrichment program, Extended School Enrichment (ESE). ESE charges a modest tuition for its services, but its demographics reflect the substantial diversity found within GISD (GISD 2011). While students have to pay to enroll in ESE, it is an economical and educational childcare option, and students incur no additional costs when participating in the SMArT program. The partnership between GISD, ESE, and SU facilitates parental consent, liability concerns, and transportation to SU from the elementary schools. The SMArT program primarily depends on a four-member team: a faculty advisor, a university civic engagement coordinator, a budget contact person, and a day coordinator.

Day coordinators train the mentors, recruit participants, run the one-hour weekly SMArT sessions, gather project supplies, and organize the end-of-program Achievement Party. Usually, only one day coordinator works at any one time, and the position gets handed down from graduating to incoming student leaders. After hearing a presentation about the program by the SMArT day coordinator, interested elementary students receive program applications. The application includes questions about the child's interest in science, favorite topic in science or math, past STEM experiences, and invention ideas. Evaluation of the applications is based on the child's creativity, expression of interest, ability to commit to attending the weekly sessions, and whether he or she has had the opportunity to participate in a similar program before.

The program optimally operates with ten to twelve elementary student-college mentor pairs, making a selection process necessary. Applications that exude enthusiasm and independence receive the most positive reviews. We also check with ESE site coordinators to avoid attendance issues. We want as many new students to have the opportunity to participate as possible, so we also prioritize new applications. The program rotates campuses every semester to give students across the district enrolled in ESE a chance to participate within their third through fifth grade window. To increase interest in attending college, and to facilitate access to laboratory resources, SMArT meets in a general biology lab at SU.

Each elementary student-college mentor pair works on an inquiry-based project or experiment of the elementary student's choice for one hour, once a week, for nine to ten weeks to improve the student's working understanding of the scientific method, encourage self-confidence in science, and increase interest in scientific careers. Students choose projects based on: (1) personal interest; (2) brainstorming with their mentors using STEM books and internet research; and (3) feasibility as discussed with the day coordinator and faculty advisor. Each week, the one-hour routine of the program includes five minutes of snack time at the beginning, forty-five minutes of project time, and concludes with a brief discussion (i.e. five to ten minutes) of what each pair did that day. The brief discussion allows the elementary school students to practice speaking aloud about their projects to prepare for the end-of-program Achievement Party.

Projects range across the scientific disciplines, varying in complexity based on the child's grade level, interest, and critical thinking skills. SMArT entertains its fair share of basic volcanoes, dissections, and robots, but each of the projects includes enough depth to last several weeks (Table 1). At the Achievement Party, during the last week of the program, the elementary student-college mentor pairs present their projects to the university, the community, and the children's parents in a celebratory, noncompetitive format. The elementary students, supported by their college mentors, stand by their posters with demonstration items in an open hall to explain their projects and answer questions from SU students, faculty, and parents about their posters. No ranking or prizes accompany the projects. The students do not present formally, but instead answer questions from a small circulating audience. We end the celebration with cake, a slide show of mentor-student pairs, and a short speech praising the students for their leaps in learning. We believe the noncompetitive atmosphere of the Achievement Party assuages presentation anxiety, supports a collaborative atmosphere within the program, and encourages students to focus on their individual explorations and learning.

Methods

Assessment Description

With IRB approval (IRB number: F10-27), ten GISD-ESE elementary school students in the SMArT program (ages 8–11, grades third–fifth) participated in the Spring 2011 assessment with written parental consent. Researchers used three anonymous assessment tools: a written prompt, a written survey before and after the program, and an individual interview after the program. We administered the written prompts individually to the students before and after the program to assess scientific problem solving skills, asking the student to design a hypothetical experiment to test a simple question. The pre-program prompt asked students to think about "what makes plants grow taller?" and the post-program prompt posed the question "what makes a paper airplane fly further?" To facilitate multiple modes of communication, researchers encouraged the students to draw, diagram, and write out their responses. They did not limit the time available to complete the task. Mentors clarified student questions or read the prompt aloud but did not help the students answer.

TABLE 1. Table of representative SMArT projects

PROJECT TITLE	ELEMENTS THAT MAKES THIS PROJECT MEMORABLE	DAY COORDINATOR SUPERVISING
How is a cookie digested?	It involved peanut butter chocolate chip cookies and how each component (sugars, proteins, and fats) was digested. Simply amazed me how much that girl knew by the end, and what's better than cookies!	Megan Lowther
Regeneration - Planaria	It was awesome watching the Planaria regrow, some even with two heads!	
What do earthworms like?	True science manipulation of variables, I will never forget the kids expression as he proudly held his freshly dug earthworms in his hands.	
How does a chicken grow?	Investigating preserved chicken eggs at different stages of development.	Meredith Liebl
How strong is a magnet?	Testing magnetic fields through several materials, with density correlations.	
What is the difference between a chicken and a snake?	Both lay eggs but the animals are very different. The student compared and contrasted snakes and chickens through dissection and research.	
How does a turtle respond to different stimuli?	This project incorporated ethics into the learning process.	Erica Navaira
How do bugs decompose?	This project involved troubleshooting smells and getting past “taboo” topics in science.	
Why do some materials generate electricity and others do not?	This project pushed me out of comfort zone of natural sciences into the physical sciences. This project is also memorable because it brought back nostalgic memories of a lit up pickle.	
How does the human eye function?	The detail and level of research that this student was able to achieve was impressive and well beyond her years. She included an accurate diagram of the human eye on her poster that was presented following the end of the program and could effectively detail the process of light entering the eye and the biological processes behind it.	Amanda Mohammed
How does a rocket fly?	This project was very hands on and the student embraced the opportunity to learn more about the process of creating a rocket and comparing his creation to real rockets. He was also able to learn more and recognize the importance behind physics, taking accurate measurements, and data analysis/recording.	
How does a frog’s tongue work?	This student started with an inquiry about frogs’ tongues but ended up uncovering much more in the process by developing a working hypothesis regarding its function. She not only developed a model of the structure of the tongue but also learned how to classify amphibians vs reptiles.	
"Are dogs' mouths cleaner than people’s mouths?"	My SMArT student loved dogs and wanted to know how much truth was in the question, “Are dogs’ mouths cleaner than people’s mouths?” By the end of our semester together this little girl was explaining, with pride, to our Southwestern Microbiology professor how she poured her own agar plates and observed a number of different bacterial colonies.	Anna Frankel
“What causes a brain-freeze?”	One semester we had a boy fascinated by the brain. By week two he and his mentor had planned experiments that would require running, standing in a freezer and Sonic slushies. To further answer his questions they topped off the semester by dissecting a sheep brain. Watching him I saw a future neuroscientist at work.	
“What makes birds’ nests and eggs different?”	As a mentor one of my favorite projects was for a little girl who loved birds and thought it was so neat that they laid eggs. It was such an adventure to hunt down so many different eggs, but her face lit up every week when she had a new type of egg to measure and compare.	

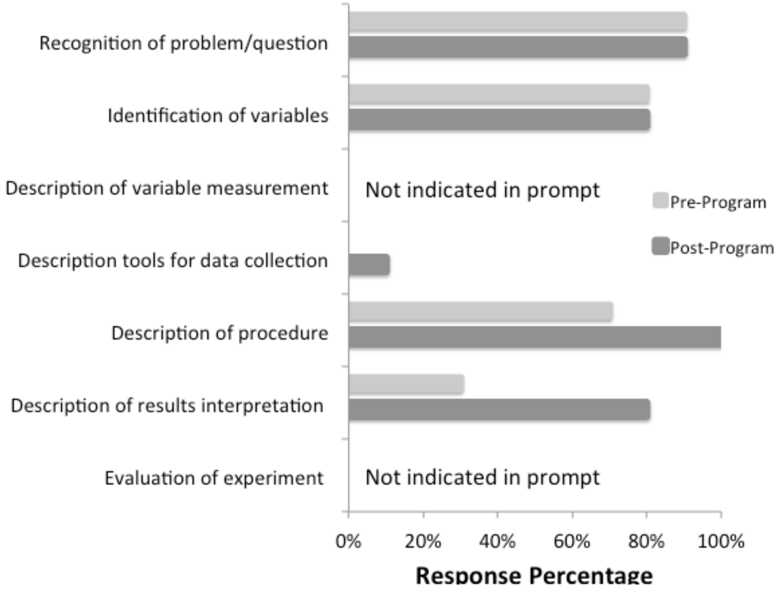

FIGURE 1. Synopsis of scored pre-program (light gray bars) and post-program (dark grey bars) rubrics on how to conduct the scientific method. Response percentage represents a positive score of one point for each of the seven parameters. Absence of a bar indicates students did not include parameter in their answer. Pre-program prompt asked about plant growth and post-program prompt asked about flying paper airplanes.

We evaluated the prompts with a positive/negative score based on the presence or absence of seven scientific method objectives (Figure 1). We administered the same individual written survey pre- and post-program (Figure 2), with five additional questions in the post-program survey (Figure 3) that explored student attitudes towards science, the scientific method, STEM career interests, and SU as the place where we met for SMArT. Students responded through a positive, negative, or neutral agreement scale towards positive statements. We administered an interview individually post-program. The audio-taped interview lasted ten minutes. We transcribed the results for later analysis. The students responded to eight open-ended verbal statements similar to the survey. We summarized six of the eight questions into agree/disagree (Figure 4). We included two other two questions, "What was your favorite part?" and "What was your least favorite part?" to look for consensus among participants in the program.

Lastly, to gain a college student perspective about the program, we asked our five day coordinators (Figure 5) to reflect on what they observed about the student learning of the elementary school students (Table 2). Over the six years that the program has been running, SMArT has employed five day coordinators (Frankel, Navaira, Mohammed, Liebl, Lowther) to help manage the program. While the directors (Burks, Pukys) managed the financial and logistical arrangements with GISD-ESE, the day coordinators did everything from recruiting elementary and college students to helping brainstorm project ideas to gathering supplies and running the day-to-day activities. All day coordinators (Table 2, Figure 5) started off as mentors working with an individual elementary school student. The day coordinators provide a longitudinal perspective on SMArT to compare with the single semester assessment study conducted by our assessment researcher (Roberts).

Results

Experimental design prompt

Before the program year started, all elementary students received a prompt to design a hypothetical experiment to answer the prompt question. Throughout SMArT, the elementary students successfully designed and completed their own experiments. As a result, in the post- program prompt exercise, all participants successfully described an experimental procedure, compared to only seventy percent before the program (Figure 1). The percentage of students who effectively described how to interpret results also increased. [Figure 1 about here] Recognition of problem and variables remained the same, while the description of variable measurement, description of tools for data collection, and secondary evaluation of the experiment prompt demonstrated little or no improvement (Figure 1). Secondary evaluation of the experiment included what the student would hypothetically change, do

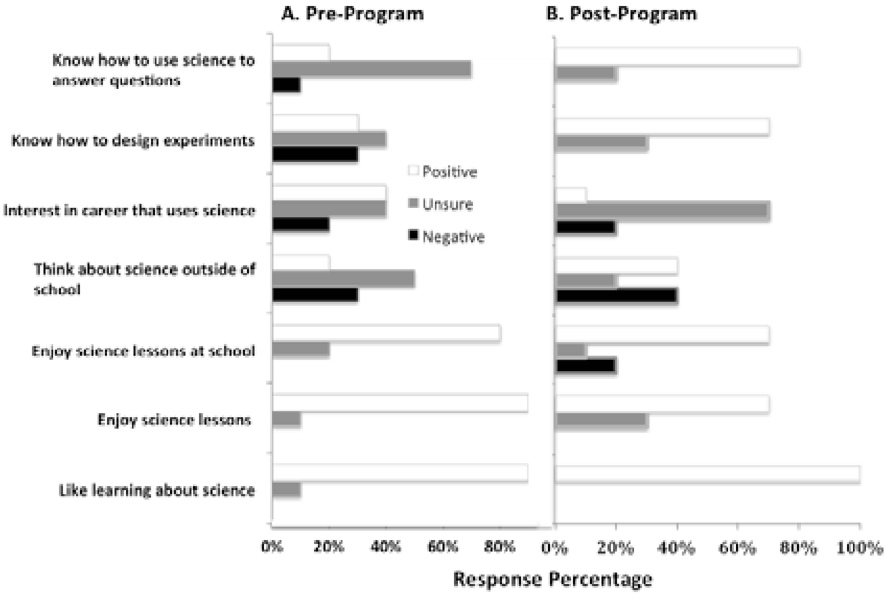

FIGURE 2. Elementary student survey responses pre-program (A.) and post-program (B.) about their feelings toward questions about areas related to scientific inquiry. Students had the option of responding positively (white bars), with uncertainty (grey bars), or negatively (black bars).

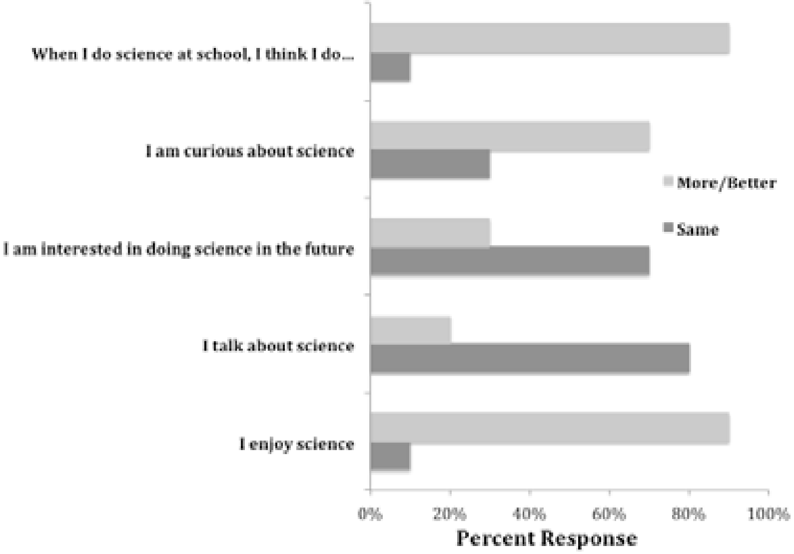

FIGURE 3. Elementary school student responses to additional survey questions post-program. These questions ask students to respond about these topics based on their experience of having completed SMArT. Students responded that SMArT increased these circumstances (light grey bar) or they felt the same (dark grey bar).

differently, or what aspect he or she would evaluate in more detail in the hypothetical "next" experiment.

Program survey

According to the survey, before the program, most students expressed either uncertain or negative responses in how to use science to answer a question about the world (Figure 2). After the program, confidence in using science to answer a question and in designing experiments improved forty and sixty percent, respectively (Figure 2). Contrary to expectations, uncertainty towards science-related careers increased after the program by thirty percent (Figure 2). Enjoyment of science remained high throughout the program (Figure 2).

Post-Program Survey, Additional Questions

Ninety percent of students said their confidence level towards science in school improved, and they enjoyed science more. Similarly, most students said their curiosity about science increased (Figure 3). Surprisingly, most students expressed no change in interest in future science activities, or the amount they talk about science outside of school (Figure 3).

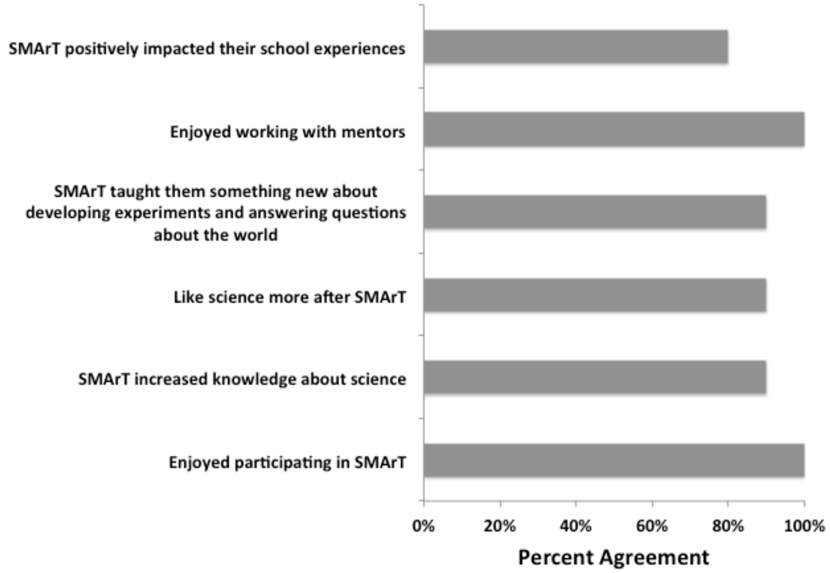

FIGURE 4. Summary of post-program interviews with elementary school students in which they talked about a number of positive outcomes of the SMArT program.

Post-Program Interview

Post-program interview responses mirrored the responses in the post-program survey's additional questions. All students enjoyed participating in SMArT and working with their mentors (Figure 4). Similar to the post-program survey, most students reported that SMArT had a positive impact on their science experience at school and on their attitudes about science (Figure 4). Almost all students expressed increased knowledge about science, how to develop experiments, and how to answer questions (Figure 4). When asked about their favorite or least favorite aspects of the program, eighty percent of students pointed towards working on their projects as their favorite part, and a high proportion (forty percent) of students failed to identify a least favorite part. A couple of students identified poster making and waiting for their mentors to arrive so they could get started on that week's portion of the project as their least favorite time spent in SMArT.

Day Coordinator and Director Reflections

Day coordinators and directors of SMArT attest to the success of the program in ways that our quantitative study could not (Figure 5, Table 2). Directly interacting with the elementary students on a week-to-week basis, those directly involved in the program witnessed the intellectual and critical thinking leaps the students made. Whether or not the experience of SMArT influences future outcomes in STEM career choices is difficult to determine. The day coordinators' and directors' testimonies make it apparent that SMArT works on a deeper level to improve the quality of the education the participants receive by challenging them to think harder about the world around them.

Discussion

Partnerships like SMArT between institutions of higher education and local school districts benefit elementary students in their cultivation of long-term critical thinking skills by providing them college science student role models. Our first detailed assessment evaluated the program's success in teaching the scientific method to elementary school students (moderately successful), increasing STEM career interest (unsuccessful), and raising student self-confidence about learning science (highly successful). Even though the sample size of our assessment is not large enough to draw statistically significant conclusions, we can identify trends of success and areas of improvement for our internal program development and advocate for the use of SMArT as a model for other STEM civic engagement programs. Based on our assessment and anecdotal testimony, we sincerely believe SMArT exemplifies a strong model for developing student inquiry.

With STEM careers comprising one-fifth of all U.S jobs, STEM education needs to increase starting from elementary through high school (Morella and Kurtzleban 2013). Even though seventy-five percent of high school girls are interested in STEM careers, women make up only one-quarter of the STEM workforce (Morella and Kurtzleban 2013). Clearly, increasing the caliber of STEM education, student confidence to enter STEM careers, and supportive role-models like those in SMArT represent necessary actions to reinforce improvements in the way education emphasizes science and math. In an era driven by STEM education, SMArT provides an engaging, hands-on STEM experience that could be better targeted to increase interest in related careers.

TABLE 2. Day Coordinator and Director Reflections

PARTICIPANTS	SMART POSITION	DATES	REFLECTIONS ON ELEMENTARY STUDENT LEARNING
Megan Lowther	Mentor and Day Coordinator	2011 - 2013	"Since I joined the SMArT program as a mentor in the fall of my freshman year, it was clear that I was participating in something big, something transformative. It never ceases to amaze me what the kids can accomplish and learn in the 10 short weeks of our program. It's the enthusiasm of both the kids, who are eager to soak up knowledge, and the mentors, who are ready to teach the next generation of scientists, that make this program so successful."
Meredith Liebl	Mentor and Day Coordinator	2009 - 2011	"I joined SMArT as a mentor the fall of my freshman year and immediately fell in love with the passionate, dynamic, and grounded program. It brings the essence of science, discovery, to each child we work with, ushering in renewed excitement to the ever changing field. These children learn, explore, and master concepts beyond their peers."
Kate Roberts	Assessment Researcher	2010 - 2011	"SMArT allows students to learn in a fun, hands-on atmosphere that truly fosters and builds upon their creativity. As an outside researcher, I was able to watch the learning and growth that took place over the course of the semester from an objective standpoint."
Erica Navaira	Mentor and Day Coordinator	2008	"By participating in SMArT I was able to help impart the inquisitive nature of science to the children, their parents, and all those involved in the project. Through my role as a SMArT coordinator, I cultivated important leadership, time management, and teaching skills that I have continued to use as a working professional."
Amanda Mohammed	Mentor and Day Coordinator	2007-2008	"As the first Biological sciences student to undertake SMArT for my undergraduate Capstone/Thesis project, I couldn't have asked for a better program to prove how inquiry based projects can facilitate lifelong learning as well as long-term memory consolidation. SMArT is a valuable asset to any curriculum style; not only is it engaging for children to implement their own projects of interest but it also increases confidence, imagination, and sets the foundation for critical thinking at an early age."
Anna Frankel	Mentor and Day Coordinator	2008-2009	"As a program, SMArT was most profoundly unique in that is was entirely student driven. While we all served as mentors, we truly were just along for the ride. Not only did we let our kiddos ask the questions, but the projects grew based on their own observations, discussions, and the additional questions they generated. The goal was to do cool science, but in such a way as to invite them to learn critical thinking, inquiry and fascination with the world. In the end, even the 'big kids' learned a few things."
Dr. Romi Burks	Day Coordinator and Director	2007 - current	"For 13 semesters, I have watched elementary students, after just ten weeks of inquiry, pull it together to explain their science to a room full of adults. As a scientist I usually rely on evidence, but I also have real faith that SMArT works."
Ms. Suzy Pukys	Director of Civic Engagement and SMArTeams Co-Director	2007 - 2011	"As someone who very much was on the outside looking in, I remember being amazed at the sophistication of the language the students used in their presentations versus their original responses on the applications."

We attribute the increased participant understanding and implementation of the scientific method, especially experimental procedure description and result interpretation, to the SMArT model. The completion of a project represents the cornerstone of the SMArT formula. The elementary student-college mentor pair either designs an experiment, an interactive model, or an experiment-model combination. The inquiry-based learning model encourages the participants to follow the scientific method by recording their hypotheses, procedures, observations, results, conclusions, and future research ideas.

While the correlations between physically designing experiments, completing an experiment, and understanding the scientific method appear clear, it remains uncertain whether the exploration of a topic through modeling reaches the same educational goals as an experiment. In a study by Vattam et al. (2011), modeling successfully illustrated and taught the structure, behavior, and function of a relationship better than a lecture. Such results support SMArT's approach of using models for teaching difficult, abstract, or unreasonably expensive subjects. For example, past SMArT topics that necessitated modeling included dolphin versus whale anatomy, large-scale robotics, how horses run, tectonic plates, the life cycle of a bird, and jungle camouflage. Modeling can include actual dissections of commercially available specimens that have similar function or body structure to the subject of interest (such as a dogfish shark instead of a great white shark), constructing robots from kits, growing crystals, and doing research to construct ecological biome models. Because we administered the written assessment tools anonymously, we do not know whether the two students who exhibited no improvement in interpreting the prompt's experimental results did a model or experiment-based inquiry model.

According to the pre/post-test prompt results, participants failed to demonstrate secondary evaluation of their hypothetical experiments in the prompt exercises both before and after the SMArT program. We defined secondary evaluation as explaining how they would alter their experiment if allowed to do it again. Possible confounding issues of this specific objective include the age of the participants, the indirect expectation of secondary evaluation in the prompt, and the lack of a separate secondary assessment trial. During the Achievement Party, personal accounts and anecdotes by mentors, day coordinators, and faculty (Table 2) support the observed improvement of the students in their proper use of scientific vocabulary, interpreting the results of their own projects, explaining how they would alter their experiment for next time, and what they would like to learn about next.

Despite the verbal and unquantifiable observation of advanced critical thinking skills, it remains understandable that the written communication and questioning of critical thinking remains difficult for elementary school students. In a study by Wan (2010), seven-year-olds effectively described the procedure of how to make Jell-O but found it difficult to explain the reasoning behind the procedure. In a similar study, third graders struggled to present a sophisticated, abstract explanation about magnetism, relying mostly on intuition and observations (Cheng and Brown 2010). Both studies support our assessment findings; the intuition to think critically lies just below the surface in this young age group. Our participants excelled in describing a procedure and interpreting results in the post-program prompt, but struggled to reach and communicate the next step of analytical thinking. Similarly, none of the assessed participants demonstrated secondary, abstract evaluation in the prompt exercises.

The similarities between these two studies and our results support the hypothesis that secondary evaluation and higher-level analytical thinking depend on age. The SMArT curriculum revolves around each individual elementary student. Depending on the students' educational and critical thinking level, the mentor guides the project to be more or less complicated, so as to create an appropriate challenge. As a result, there can be large differences in complexity between individual children and their ability to critically and abstractly analyze their projects. In future assessments, we intend to perform an assessment at the end-of-program Achievement Party; an audio recording of their project explanations, for example, would provide a concrete opportunity for the students to apply secondary, abstract evaluation of an experiment. Based on informal observations over the years, we noticed that some of the younger students struggled with this challenge while more of the older participants answered more confidently when asked to further analyze their experiments during poster presentations. We believe most of the SMArT participants execute some level of secondary evaluations of their projects and should be assessed through direct oral questions like those the students receive at the Achievement Party poster presentations.

The assessment results concerning the second major goal of SMArt, to increase confidence in STEM subjects and interest in STEM-related careers, illuminated areas to improve within the program. Student interest in participating in science-related activities in the future remained fairly constant for the duration of the program. We attribute this partly to the non-random nature of the SMArT program, given that participants have already demonstrated an enthusiasm for science in their applications. Unexpectedly, the elementary students expressed a higher degree of uncertainty towards STEM careers after the program than before, despite a demonstrated increase in STEM subject interest.

We expect that the short duration of the program, as well as the students' young age, contributed to the perceived limited impacts of the program on STEM career interest as extrapolated from the survey results. However, personal experience of day coordinators who talked with the students helped solidify our assertion that the program does extend students' experiences of science outside the classroom. While the students enjoyed the laboratory experiences, we believe the students did not make connections between SMArT activities and STEM career paths. In the future, short STEM career presentations to the elementary students by their mentors or science faculty may introduce and encourage science-related careers; for example, mentors could give short presentations on their personal educational, and career goals, and current research project.

Overall, the SMArT program stands as a strong model for colleges and universities seeking to make a lasting impact on the next generation of STEM professionals in their community, by providing a unique hands-on experience and dynamic exploration of the scientific method, the core foundation of any STEM education. Ahead of its time, the SMArT model supports the 2013 Next Generation Science Standards (NGSS) issued by the National Research Council, which has been adopted by twenty-six states (Cardno 2013). Like the SMArT model, the NCSS encourages the use of science and engineering hypothesis-testing learning environments where students engage in problem solving activities, modeling, investigations, data analysis, and math skills (Cardno 2013).

As excitement for STEM education reaches state-level curricula, it will take time to teach teachers how to implement the new classroom standards and increase the number of educators comfortably teaching STEM. Currently less than half of elementary school teachers express confidence in teaching science, and only four percent feel prepared to teach engineering (Banilower et al. 2013). Joint programs like SMArT between post-secondary institutions and school districts can amend the disparity between the science and math education students sometimes receive at school, and what they need if they are to succeed. Some school districts already turn towards business professionals, community specialists, and universities to bring science to life in the classroom through real-world examples (DeNisco 2013). Programs such as SMArT demystify science and math, bringing a highly diverse and opportunity-rich field to the fingertips of elementary students. There will always be a place for civic engagement programs like SMArT to bring the enthusiasm of college students to elementary students, but perhaps we need programs like SMArT now more than ever to bridge the education gap.

Acknowledgements

SMArT began as a project through a Brown Fellowship for Innovative Teaching supported by the Provost's Office at Southwestern University. We acknowledge additional internal financial support from The Paideia Program, The Office of Civic Engagement, and most recently, external funding from the W. D. Kelley Foundation. Linda Southwick and Christy Schaller in the Department of Biology graciously help with supply acquisition and project development. Sarah Hensley also helped get the SMArT program up and running in 2007. We appreciate the efforts of many Natural Science faculty at Southwestern to provide advice for SMArT projects. Jan Williams and the entire staff of Extended School Enrichment make the partnership possible. We appreciate the comments of Dr. Sarah Brackmann, SU's Director of Civic Engagement, on this manuscript.

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PROJECT REPORT

An Engineering Perspective on Collaborative Client-Based Service-Learning Projects in an Introductory Environmental Engineering and Science Course

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Abstract

The partnership of client-based course term projects described in this paper is an approach to enhance students' confidence in researching complex environmental issues and to affect their environmental perspective in the process. This paper presents an adaptable model that can be used in multiple different situations. In this two-year longitudinal study, we partnered an introductory environmental engineering and science course of approximately 250 students per year with an introductory marketing course of approximately 70 students per year. The courses partnered on semester-long, collaborative term projects focused on the adoption of sustainable environmental solutions within the community. Before and after the term project, anonymous surveys were administered to assess changes in respondents' views on the importance of their findings and how they might contribute to a solution for the community. We conclude that the collaborative term project model described in this paper improves a student's confidence and environmental perspective while developing solutions to complex environmental issues.

Introduction

Developing sustainable, real-world solutions to energy and environmental problems often requires a holistic approach, meaning that viewpoints from economists, social scientists, and environmentalists must be considered (Mihelcic et al. 2003). However, these wide-ranging viewpoints are difficult to simulate without extricating students from the classroom. Many universities have real-world problems within their communities in areas such as energy efficiency, water efficiency, and solid waste management, but they do not always have the time or resources to examine the problems in depth. If done correctly, collaborative client-based service-learning projects can fill both of the aforementioned gaps. Previously published studies indicate the importance of taking projects outside the classroom and implementing them in the local community to solve a problem for a client who has a measurable need. Several sources (Coyle et al. 2006; Carlson and Sullivan 1999) indicate that implementing course projects in a real-world context not only increases the pride the students take in the results, but also benefits the community. Additionally, providing students the opportunity to develop solutions to problems they observe concerning energy and the environment can help shape behavior and promote lifelong dedication to sound environmental practices (Hungerford and Volk 1990). Educating students with methods that develop a thirst for lifelong learning at the right time and in the right manner is also important. Students learn in various ways, and this can be particularly true for "millennial" students (born between 1977 and 1998), who are characterized by their ability to multi-task in a rapidly changing environment (Thielfoldt and Scheef 2004). Knight et al. (2007) showed that providing students with a hands-on, team-based project early in their education aids in student retention and long-term interest in that discipline. Further, science and engineering students sometimes exhibit a void in "human" skills, such as communication and teamwork (Mills and Treagust 2003). A collaborative team-based project can enhance such skills by building confidence amongst the students (Hammervoll 2011).

Currently, there are no readily available peer-reviewed articles outlining collaboration between a junior-level environmental engineering and science course and a junior-level marketing course as a means to take a more holistic approach to a client-based service-learning project. Furthermore, while precedent for developing coordination between marketing and engineering courses is available, it is not abundant (McKeage et al. 1999; Lunsford and Henshaw 1992). This paper examines the connection between an introductory environmental engineering and science course and an introductory marketing course as a means to increase students' confidence in researching a complex environmental issue and to change students' environmental perspectives through the completion of a client-based service-learning project. It presents a model for collaborative client-based service-learning projects that was assessed using survey results from an introductory environmental engineering and science course and can be adapted to meet the needs of other universities.

Background

Our university requires students to take a robust core curriculum, which includes 26 courses in varying disciplines such as math, history, chemistry, and physics. Students choosing not to major in an engineering discipline must take an additional three-course engineering sequence. Each year, approximately 180 students elect to take the environmental engineering sequence of courses. The semester-long engineering design project described in this paper is hosted within the first course in the sequence, titled "Environmental Science" (EV300), which introduces basic environmental topics. Environmental engineering and environmental science majors take a course very similar to EV300, titled "Environmental Science for Engineers and Scientists" (EV301), which has more engineering design requirements but the same term project parameters. The objective of EV300 and EV301 is to provide students with a broad understanding of current global and local environmental issues and their subsequent social, economic, technological, and political impacts. Specific foci include natural ecosystem processes, the effects of pollution on human health, the assessment of risk by pollutant type, the environmental effects of energy use, and air pollution concerns. A total of approximately 250 students per year take either EV300 or EV301 (Pfluger et al. 2013).

Environmental Engineering and Science Course and Term Project Description

The purpose of the term project for EV300 and EV301 is to develop solutions to local environmental problems by applying the scientific method. Student groups (three or four students) are asked to develop a hypothesis with data collection procedures to conduct a scientific experiment that supports one of two project types: client-based or knowledge-based. Project sponsors define client-based projects by identifying a problem and providing the scope of their desired outcomes, while personal scientific curiosity and the desire for additional knowledge provide the basis for knowledge-based projects. Students gather scientific data and couple them with social or cultural research to support their final designs. Groups with outstanding projects have the opportunity to present their findings to their respective sponsors.

Our university's introductory marketing course (MG380) had introduced a "Green Marketing" campaign project, which provided a logical linkage to an environmental engineering and science course with a sustainability-focused term project. Marketing can play a key role in effectively relaying technical engineering or science information to the local community in an understandable and acceptable manner, an area on which our introductory environmental engineering and science course does not focus.

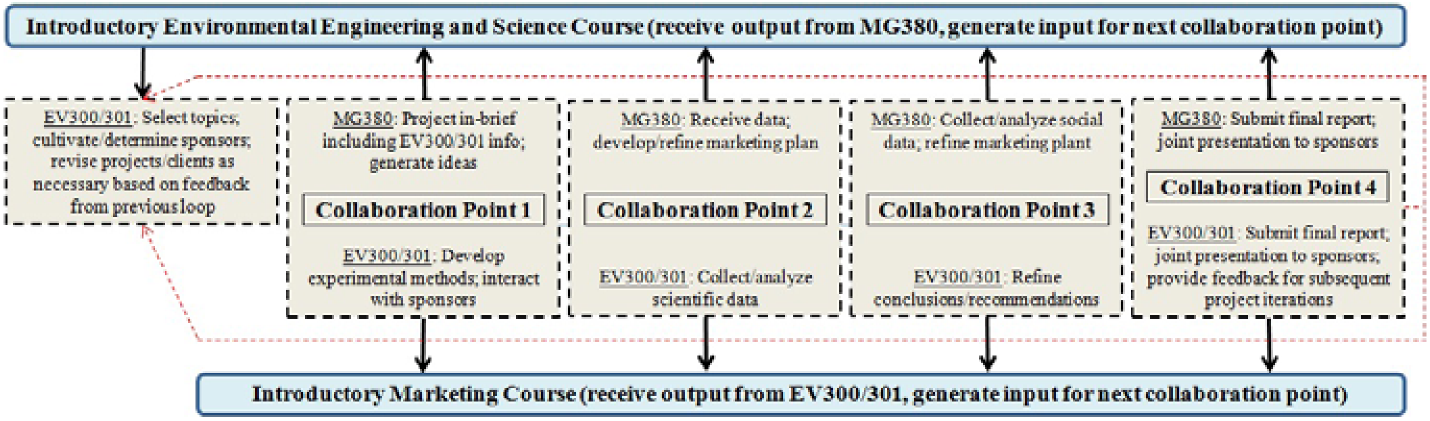

FIGURE 1. The direct collaboration points between the introductory marketing and introductory environmental engineering and science courses are shown. Each box denotes a separate collaboration point and outlines the expected exchange of information or products. The feedback loop identified uses one iteration's outputs as injects for the next iteration of projects. Adapted from Pfluger et al. (2013).

Term Project Model

The EV300/301 term project commenced earlier in the semester than that of MG380, allowing for topics, appropriate hypotheses, and experimental methods to be developed and vetted by the instructors. If conducting a client-based project, term project groups were expected to meet with their sponsors to identify the problem and the sponsor's requirements for a potential solution. During the green marketing campaign project in-brief for MG380, the EV300/301 topics and methods were presented, allowing the marketing student groups to ask questions, develop ideas, and select which project they would like to support (Fig. 1, Collaboration Point 1). Client-based term project groups were expected to maintain communication with their sponsors to keep them apprised of their progress and ensure that their experimental design would not hinder the sponsor's day-to-day operations. Over the next several weeks, student groups from EV300/301 conducted scientific experiments and gathered data necessary to support their hypotheses. These results and potential conclusions were shared with the MG380 students so that they could begin developing a targeted marketing plan (Fig. 1, Collaboration Point 2). The marketing students typically conducted social change surveys to assess the effectiveness of their desired marketing campaign. These data were shared with the EV300/301 student groups, allowing the environmental engineering and science students to refine the conclusions, solutions, and recommendations in their final report (Fig. 1, Collaboration Point 3). The final point of collaboration occurred when the final reports for both courses were submitted. If applicable, student groups were expected to present their joint findings, solutions, and recommendations concerning the observed environmental problem to their respective project sponsor (Fig. 1, Collaboration Point 4). The collaboration efforts were expected to provide all of the student groups with a more holistic approach to either recommending or marketing a solution to an environmental problem, which could then be conveyed in their final written report.

The model described in Figure 1 is not a linear process. The outputs at the end of the model, such as student surveys, reflections, and client feedback, all serve to refine the next iteration of projects as the inject for the process to restart. The outputs allow for continual improvement and refinement of the process, as well as the exchange of potential new projects or needed improvements to work already conducted and presented.

This model provides a framework that can be applied to introductory environmental engineering and science courses at other universities for the development of a collaborative and client-based service-learning project. The model is adaptable, as the user can add guidelines or more specifically define collaboration to "fit" the framework and better suit the needs of the courses and students involved.

Example Projects at our University

Projects at our university have encompassed a wide range of topics based on locally observed environmental problems, including recycling, energy usage, food waste generation, solid waste reduction, and water quality (Table 1).

Assessment

The instructors administered anonymous surveys to assess how well the term project model enhanced a student's confidence to research a complex environmental issue within the construct of a client's needs, as well as his or her change in environmental perspective. The anonymous survey was administered only to the environmental engineering and science students, and these are therefore the only data that are presented. The same survey was given prior to the initiation of the project and again after the final project report was submitted using a 5-point Likert scale to enumerate responses to the six questions (Table 2). Data analysis was conducted in R (R Core Team [2012]). Welch's t-test was used for comparison purposes due to the potential for unequal variances amongst the survey groups. This test serves as a nonparametric adaptation of the Student's t-test. Chi-square tests were performed when the data were not robust enough to support the t-test.

Pre- versus Post-Project Assessment

As a whole, the client-based service-learning project and the collaborative project model enhanced students' confidence in their research skills, as well as positively changing their environmental perspectives based on personal student ratings (Table 3) when analyzed using Welch's t-test. Questions 1–4 exhibited statistically significant ($\alpha = 0.05$) differences between the before and after means of each question, and when student responses prior to and after the term project were compared, a longitudinal improvement in each student's experience was observed across all questions. Questions 1–4 measure a student's values, whereas questions 5 and 6 directly analyze a student's motivation. It is positive and reinforcing that a sustainability-focused, collaborative service-learning project improved students' environmental values and induced a statistically significant difference between the means of the before and after surveys on questions 1–4. Although the results from questions 5 and 6 were not statistically significant, they do show a slight increase in

TABLE 1. Example environmental term projects. Complete projects have both a "✓" in the "Course" columns coupled with an "X" in the "Topic Type" columns. Adapted from Pfluger et al. (2013).

Project Description	COURSE		TOPIC TYPE	
	EV300	EV301	Client	Knowledge
Analysis of energy use by machines left on overnight in a gymnasium.		✓	X	
Impact of plastic wrap on laundry bundles.		✓	X	
Food waste generation due to dining style (multiple variations).	✓		X	
Recycling system analysis in the dormitories (multiple variations in both courses).	✓	✓	X	
Potential for biogas generation using organic food waste from cafeteria.		✓	X	
Impact of different laundry services on water consumption.	✓		X	
Impact of noise on common study areas.	✓			X
Impact of shower arrangement on water conservation.	✓			X

TABLE 2. Example environmental term projects. Complete projects have both a “•” in the “Course” columns coupled with an “X” in the “Topic Type” columns. Adapted from Pfluger et al. (2013).

Question 1: I possess the skills to identify, research, and report on an environmental topic/issue in my community (confidence).

Question 2: Researching possible solutions to environmental problems in my community is important (importance).

Question 3: The faculty values my data collection, results, and conclusions (faculty-valued).

Question 4: Fellow students would value my data collection, results, and conclusions (peer-valued).

Question 5: Working on a community project in class would enhance my motivation and understanding (perception).

Question 6: I value the grade I receive for my project more than the intrinsic value of my work contributing to solving an environmental problem in my community (intrinsic value).

student motivation. A refinement of the survey questions is warranted to explore this in depth.

The client-based term project model created an educational experience with tangible and relevant results through the connection between the environmental engineering and science course, the marketing course, and the community sponsor's needs. After the project, students felt more confident with their skills to identify, research, and convey information through a report on a complex environmental issue (question 1). All of the students intrinsically felt that it was important to identify and develop solutions to community-based environmental problems (question 2). The real-world context and relevancy of the results interested the students and indicated an increased level of personal pride in the students' individual work and greater potential for lifelong learning. Lastly, we hoped that students would be more motivated when working on service-learning projects that had potential impact in the surrounding communities (question 5); however, there was very little change in students' perceptions over the duration of the project.

Project Type Assessment

In addition to the opportunity to select a service-learning project with a definite sponsor in the local community to whom they could then present recommendations or solutions, student groups also had the opportunity to develop their own project based on personal observations and curiosities. The sponsor-driven groups participated in a client-based project while the other student groups participated in a knowledge-based project. Data from both project types were analyzed using a chi-squared distribution after stratifying the surveys first by time period (before or after the project) and by type of project (client- or knowledge-based) (Table 4). In several cases, the student groups had not yet selected their project topic upon the pre-project survey administration, resulting in the difference in sample sizes before and after the project. The survey results of those students who had not selected a specific client-based project were assigned to the knowledge-based project category in determining the pre-project means. During the post-project survey, students then identified their project as either a community- or knowledge-based project and their results were grouped accordingly.

The results of the pre-project survey indicate that a student's response to questions 1–4 is dependent upon the type of project on which he or she is working ($\alpha = 0.05$). This is not the case after the project, with results indicating that a student's response is independent of the type of project on which he or she worked. The shift in dependence of a student's response from being dependent on the type of project to being independent of that same project signifies that the benefit of the collaborative nature of this model is a stronger force on student perception and experience than project type. A factor contributing to the observed regression towards the mean may be that in many cases a clear delineation did not exist between project categories. Some of the projects classified as knowledge-based included aspects of relevance to a client or the community (Table 1). Additionally, students who selected knowledge-based projects scored higher, on average, on questions 1 and 2 prior to the project initiation than those students who selected client-based projects. This may indicate that a knowledge-based project, in which the student personally develops a testable hypothesis from an observation, initially influences personal satisfaction more than a client-based project. Conversely, after the completion of the project students who worked on client-based projects scored higher on questions 1–5 than those students who worked on knowledge-based projects. This term project is

TABLE 3. Welch's t-test results comparing "before project" and "after project" survey responses enumerated using the 5-point Likert scale. Each respective question number is identified by "Q" and the question number.

		Mean of Pre-Project (n=135)	Mean of Post-Project (n=191)	Mean of Post-Project (n=191)	∆ Means (Pre- to Post-Project)	p-value
Q1	Confidence	3.78	4.20	4.20	0.42	<0.001
Q2	Importance	4.04	4.26	4.26	0.22	0.015
Q3	Faculty-valued	3.63	3.84	3.84	0.21	0.026
Q4	Peer-valued	2.88	3.34	3.34	0.46	<0.001
Q5	Perception	3.72	3.83	3.83	0.11	0.268
Q6	Intrinsic Value	3.50	3.64	3.64	0.14	0.190

the first experience that many of the students have had with a client-driven project where the sponsor initiated the project and requested specific deliverables and outcomes. To the students, this fact may have transformed what would have been "just another project" into a significantly larger and more rewarding accomplishment, since there was an invested person or organization on the receiving end of the final term project submission. The personal satisfaction associated with such a rewarding experience may have increased the post-project scores of the client-based projects over those of the knowledge-based projects. Further, when comparing each respective question by topic type from pre- to post-project, all of the means increased except for the knowledge-based project on question 5, which decreased from 3.72 to 3.64. Such a widespread increase in student perception indicates the positive effect that the service-learning project model had on the students' confidence to research a complex environmental issue within the construct of a client's needs as well as their overall environmental perspective.

Conclusions

Our university partners an introductory environmental engineering and science course with an introductory marketing course to study and provide marketable recommendations or solutions to local, real-world environmental problems. This construct provides a vehicle for student-client interaction, benefitting both the students and the community. The collaborative model assessment yielded three main results: students prefer client-based service-learning projects to knowledge-based projects; students' environmental perspectives were improved regardless of the type of project; and the student experience was positive overall. The opportunity to research and analyze local, real-world environmental problems based either on personal curiosity or driven by a sponsor's requirements help to provide tangible results that improve students' views and perceptions of the importance of the environment. The collaboration and interaction with real-world clients allows environmental engineering and science students to increase their confidence in researching a complex environmental issue and has a positive effect on their environmental perspectives.

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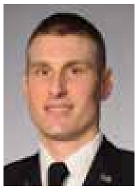

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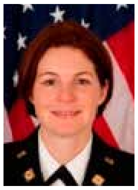

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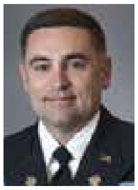

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