


SPECIAL SECTION ON MATHEMATICS & CIVIC ENGAGEMENT

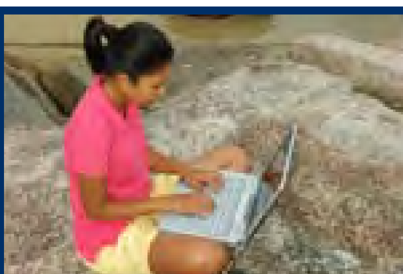
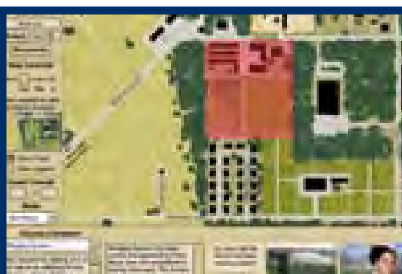
SCIENCE EDUCATION & CIVIC ENGAGEMENT

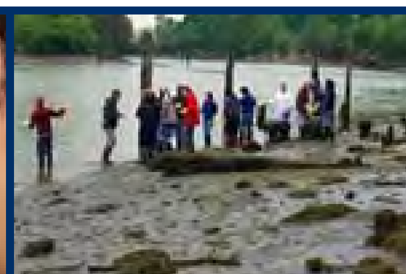
AN INTERNATIONAL JOURNAL

Volume 3

Issue 1

Winter 2011



Science Education & Civic Engagement: An International Journal
Volume 3: Issue 1, Winter 2011

Publisher
Wm. David Burns

Editors
Trace Jordan
Eliza Reilly

Managing Editor
Marcy Dubroff

National Center for Science and Civic Engagement
1604 New Hampshire Ave., NW
Washington, DC 20009
202.483.4600
www.ncsce.net

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.

Contents

From the Editors

This issue of the *Journal* presents a diverse collection of articles and reports that demonstrate the effectiveness of using civic questions to enhance science learning.

Two of the articles address the role of pedagogy in improving science learning among female students. J. Kasi Jackson (West Virginia University) and Jane Caldwell (Washington and Jefferson College) discuss the use of feminist pedagogies within a large science course for non-majors. For readers interested in attracting more diverse students to undergraduate science majors, Ellen Mappen (National Center for Science and Civic Engagement), David B. Knight and Stephanie L. Knight (both of Pennsylvania State University) provide a valuable review of current literature on how civic engagement pedagogies can increase the representation of women undergraduates in STEM disciplines.

The other four articles in this issue exemplify the rich potential offered by environmental problems to teach a wide range of topics in science and mathematics. Peter Bower (Barnard College), Ryan Kelsey and Frank Moretti (both of Columbia University) have written a research article on the multiyear implementation and assessment of their innovative simulation called "Brownfield Action." Abour H. Cherif and Linda Michel (DeVry University) have collaborated with Farahnaz Movahedzadeh (Harold Washington University) to develop and teach an engaging role-playing activity on the environmental release of genetically modified mosquitoes as a strategy to control malaria. Turning to mathematics, Thomas J. Pfaff, Ali Erkan, Jason G. Hamilton, and Michael Rogers (Ithaca College) have linked their teaching of calculus to an evaluation of climate change. To conclude the issue, W. Lindsay Whitlow (Seattle University) has partnered with Sara Hoofnagle (Einstein Middle School) to contribute an article with the wonderfully evocative title of "Mud, Muck, and Service."

As always, we wish to thank all the authors for sharing their work with the readers of this journal.

— *Trace Jordan and Eliza Reilly*
Co-editors in chief

RESEARCH ARTICLE

Brownfield Action

An Inquiry-based Multimedia Simulation for Teaching and Learning Environmental Science

Peter Bower
Department of Environmental Science, Barnard College

Ryan Kelsey
Columbia Center for New Media Teaching and Learning, Columbia University

Frank Moretti
Department of Mathematics, Science, and Technology in Education Teachers College, Columbia University

Introduction

According to the EPA there are presently over half a million brownfields in the United States, but this number only includes sites for which an Environmental Site Assessment has been conducted. The actual number of brownfields is certainly into the millions and constitutes one of the major environmental issues confronting all communities today. Brownfield Action (BA) is an award-winning, web-based simulation and curricular model developed and used for the last ten years by Peter Bower, a senior lecturer at Barnard College, in his introductory environmental science course, to teach undergraduate non-science majors about brownfields, toxification of the environment, and civic engagement. (See Figure 1.) The BA multimedia environment was constructed in conjunction with the Columbia University Center for New Media Teaching and Learning (CCNMTL). BA is currently in use at nine additional colleges, universities, and high schools. Successful widespread, collaborative use of BA was made possible by development of modularized software, a robust server and website for outreach and peer support, as well as faculty training seminars. The testimony of instructors using the BA simulation in their courses, as well as an independent professional evaluation using largely formative methods have validated that BA produces a significant increase in student understanding and learning across a wide spectrum of uses. The focus of this article will be on its use at Barnard College (BC).

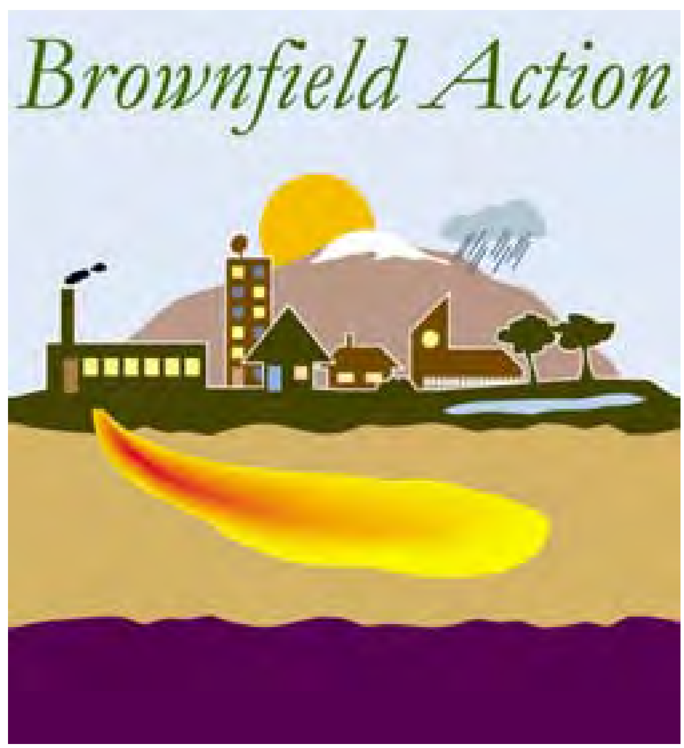


FIGURE 1. The Brownfield Action logo.

At the heart of BA is a web-based interactive learning simulation in which students explore and solve problems in environmental forensics. The playing field contains over two million data points in a three-dimensional grid whose playing surface is 2000 × 3200 feet (~150 acres) in a fictional town known as Moraine. Grid points hold many different types of natural data, including surface topography, depth to water table and to bedrock, soil or sediment type, and vegetation. The simulation's graphical user interface (GUI) allows students to utilize a host of tools, including: seismic reflection and refraction, ground-penetrating radar, magnetometry and metal detection, soil gas, and well and ground water sampling using drilling and push techniques. The GUI also includes numerous details about the fictitious town of Moraine: infrastructure (buildings, roads, wells, water towers, homes, businesses, and underground pipes and tanks), a municipal government complex with relevant historical documents and permits, and a town history and storyline that includes residents who may be "interviewed" by students (see Figure 2).

The story that unfolds in the simulation is one of groundwater contamination in Moraine and the resulting underground contaminant plumes. As students become familiar with the simulated town and the history of the abandoned plant owned by Self-Lume, students gradually reconstruct the details of an all-too-familiar narrative. The Self-Lume factory, which until recently manufactured radioluminescent signs, has been badly mismanaged and employees have dumped radioactive materials into a septic field. A gas station is also discovered

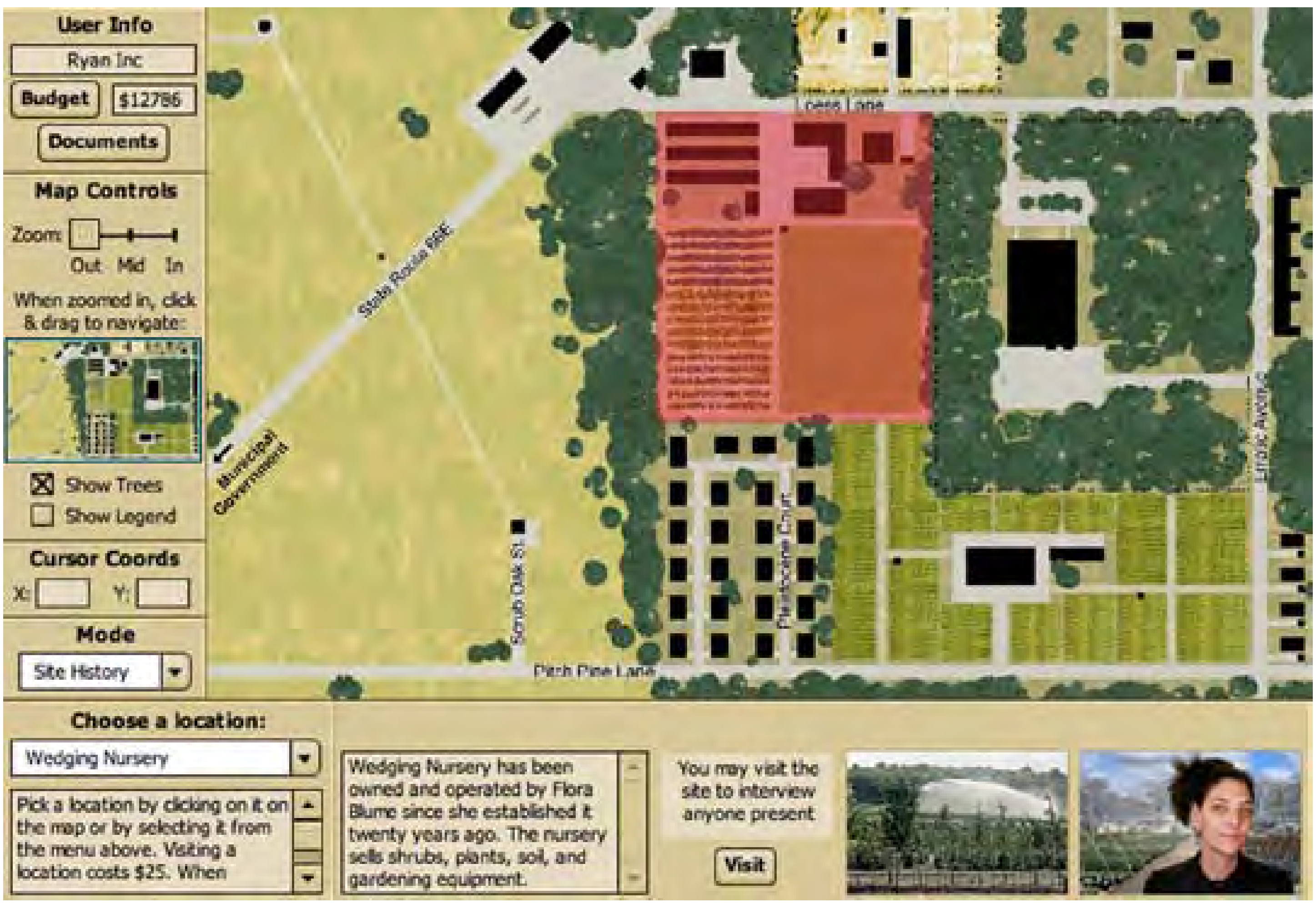


FIGURE 2. The BA site map is shown here with the History tab activated and with a student visiting the Wedging Nursery (highlighted in red). Photos of the nursery as well as the owner of the nursery (one of the characters in the BA story) appear and a video may be activated in which the owner answers a series of questions. Students may ask further questions (again at a price) by activating the interactive question mode. See the Supplemental Documents section for more screenshots of the BA simulation.

to have a leaking underground storage tank. Both have contaminated the local aquifer. Malls-R-Us wants to build a shopping center on the factory site. It is the job of the students to act as environmental assessors to determine if the site is safe.

The Simulation at BC

BA is a collaborative exercise that forms the foundation for twelve laboratory sessions. Pairs of students form environmental consulting companies, which are part of a storyline already in progress that each student must "buy into." Each company begins its investigation by viewing a simulated cable access program depicting an interview with the Malls-R-Us developer who describes plans to convert the abandoned Self-Lume factory site into a shopping mall (Figure 3). The teams then sign a contract with the developer, for whom they must perform a Phase I Environmental Site Assessment (ESA) of the abandoned factory and prepare a report for the developer on the advisability of proceeding with construction of the mall. The contract summarizes in detail the obligations as well as the goals for the semester-long investigation and provides a budget. Everything from the initial visual reconnaissance to the hiring of subcontractor firms to perform specific tests, costs the student company money, drawing from the budget provided in the contract. The simulation and supporting materials draw the students into active involvement, enmeshed in a "real," integrated world with a mystery to be solved. Each company must learn to obtain the maximum amount of information at the lowest cost, information that will help them make more important (and expensive) decisions later in the semester in order to fulfill their contractual obligations. Student companies compete to maximize profit while producing a report that accurately reflects reality.

Students obtain documents and historical and anecdotal information by visiting the municipal complex or interviewing individuals within the simulation (see Figure 4).

Students must pass tests and become "licensed" before utilizing any of the various forensic tools (see Figure 5). While students companies may begin drilling at any time, they quickly learn that this is a very expensive procedure not to be attempted in a blind search for contamination.

While BA is a collaborative project at BC, each student produces her own Phase I ESA report due seven weeks into the term using the information acquired by the team. After the Phase I ESA and the discovery that the municipal well has been contaminated, all of the student companies are hired by the EPA and work together for three weeks on a Phase II Environmental Site Investigation with each student preparing a Phase II report detailing the sources, nature, and extent of the contamination. Student companies also work as detectives to build character and story maps in order to understand the specific roles of individuals at the abandoned factory site. They assist prosecutors from the Department of Justice with forensic evidence and help build both civil and criminal lawsuits against

FIGURE 3. **Seymour Buckmeister, president of Malls-R-Us, is interviewed by Frank O'Ryan on Esker County Cable News Access and describes his plans to convert the abandoned Self-Lume factory in Moraine into a high-tech mini-mall.**

FIGURE 4. **The GUI showing an interview with a member of the Moraine Volunteer Ambulance Corps. Here a student can visit each of the town's locations, developing anecdotal records by interviewing local townspeople and requesting and viewing documents.**

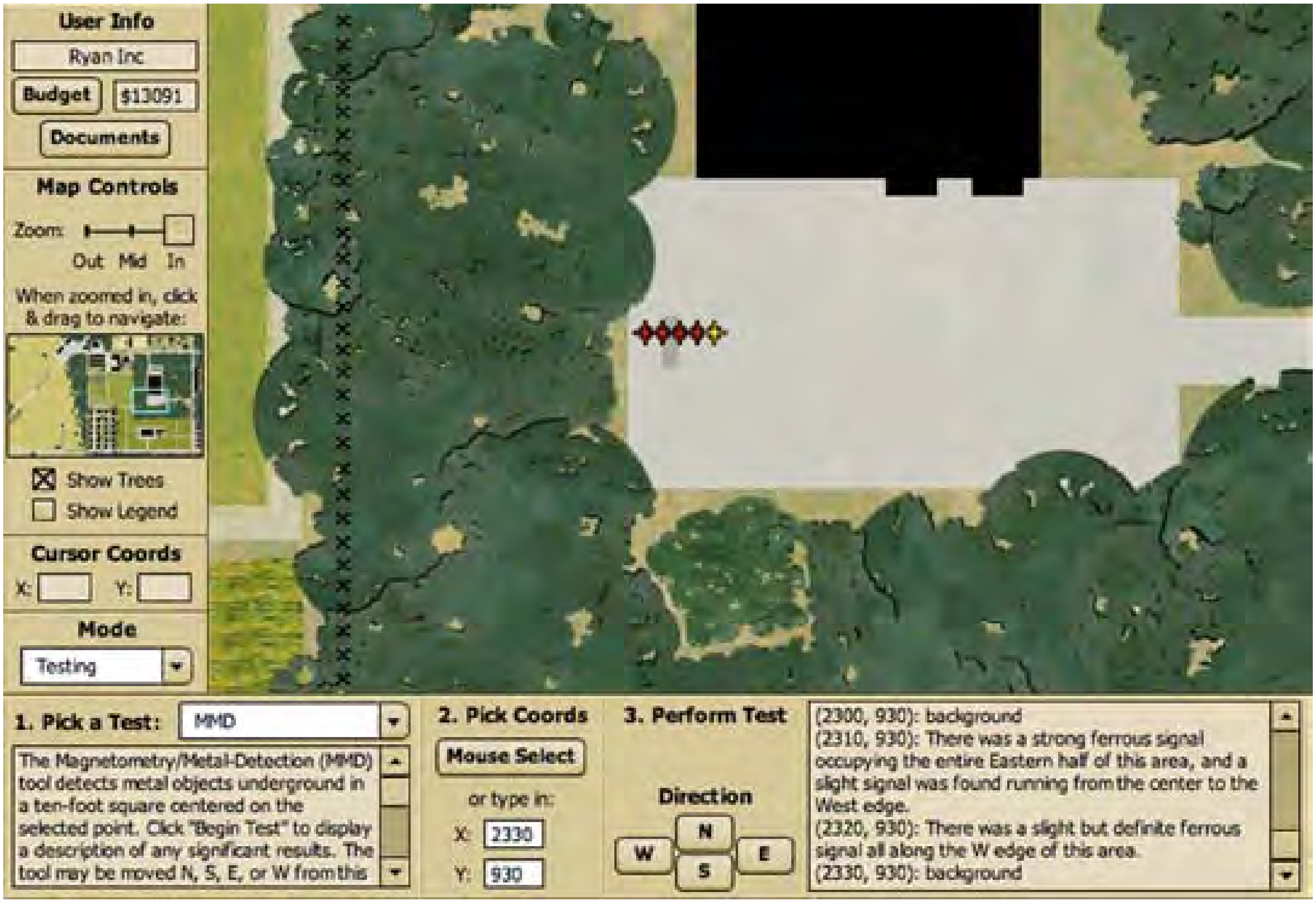


FIGURE 5. The GUI showing the use of the magnetometry and metal detection tool at the Self-Lume site. Here eight test options (such as ground penetrating radar, soil gas, metal detection and magnetometry, push and drill technologies, seismic profiling, etc.) are available, each with links to online reference material, a certification quiz, a practice option, and a "do test" option that incurs costs.

the responsible parties. In the final two weeks each student prepares a Phase III report detailing measures for remediation.

Lectures and one-on-one contact in the laboratory provide strategic thinking tools for planning a cost-effective investigation that evolves over time as the reality of the actual site emerges from ambiguity. Lectures also provide the information that students need to perform the Phase I, II, and III ESAs. This includes an interdisciplinary array of subjects, including: basic civics and the role municipal government, land-use and zoning, the laws governing the flow of groundwater and contaminant plumes, soils and sediments, drinking water standards, radionuclides, organic chemistry, environmental law, the economics of real estate, brownfields, toxicology, and topographic maps. The main objective of this integrated approach is to create a curriculum that provides students with an inquiry-based, interdisciplinary, and realistic construction of knowledge, one that contains ambiguity but also one that forces students to make choices based upon their perceptions of the interlocking realms of knowledge, theory, and, especially, direct observation and experience, and then to react and adapt to the consequences of their choices. In so doing, students are given multiple opportunities to tackle the complexity of a large-scale interdisciplinary problem and achieve an understanding of the interdisciplinary nature of the scientific process and its complicated relationship with economic, social, and political structures.

Students Use of BA

BA has been used for ten years as the foundation for one semester of the year-long Introduction to Environmental Science (IES) course taught at BC. The course has two 1¼ hour lectures and one three-hour laboratory per week; there are eight laboratory sections of fourteen students each. These 112 students reflect the composition of Barnard as a whole: the 2,261 female undergraduates come from forty-seven states and more than twenty-seven countries; 12 percent are African-American, Latina, or Native American; 24 percent are Asian. Students are roughly evenly divided between first-, second-, third-, and fourth-year students. Approximately 8 percent of the students who take IES with BA become environmental science majors and move directly into upper level science courses; approximately 16 percent of these students major in another science; 76 percent of the students are, therefore, non–science majors taking this course to fulfill their science requirement. For most, it is their last academic contact with science. The development and implementation of BA at an independent women's liberal arts college was inspired in part to challenge the scientific interest and skills of female undergraduates, a demographic group that is historically underrepresented in the natural sciences.

STEM Education

Data from Barnard College show that 10 percent of the non–science undergraduates who take BA go on to take more advanced STEM courses, especially in environmental science but also in all the sciences. The question of whether BA impacts the decision to take advanced STEM courses has not been specifically studied, but anecdotal evidence, including unsolicited student comments, suggests that 1–2 percent of the BA cohort who never considered taking any more science do so as a result of their BA experience.

Assessment

A range of qualitative formative evaluation strategies have been employed using a modified model of Design Research (Bereiter 2002; Collins 1992; Edelson 2002). As with any design study, the aim has been to iteratively improve the intervention rather than trying to prove its efficacy through attempting to control the innumerable variables at play in this course; in this case, the course design, teaching strategies, technology, as well as the use of the technology have been reviewed and iterated many times. Evaluation techniques have included classroom observations, surveys, independent assignment analysis, and structured interviews. All assessment activities to date have been focused on student learning, especially on student learning with today's technology. Whenever possible, student perspectives have been incorporated into the evaluation design.

A comprehensive report on the design process of BA and the evaluation techniques used from 1999–2003 can be found in Kelsey (2003). This study chronicles the discovery, design, development, implementation, and evaluation of BA over a four-year period from prototype to full-fledged semester-long lecture and lab experience. Multiple formative assessment techniques were designed and implemented culminating in a qualitative ethnographic approach of monthly interviews of eight student volunteers to determine the impact of BA on the evolution of each student's learning process and attitude towards science through the duration of the course. 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, that BA improved student retention, and that students made linkages in their reports not likely to be made in a traditional teaching framework. It was 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, learned more content and in greater depth. This study also showed that BA supports the growth of each student's relationship to environmental issues and promoted transfer into the student's real-life decision-making and approach to careers, life goals, and science.

In 2003, BA was selected as a Science Education for New Civic Engagements and Responsibilities (SENCER) model curriculum. This award recognized the contributions BA has made to both teaching and inquiry-based learning as well as to the application of digital technology in the classroom. The award also recognized that BA encouraged civic-engagement by integrating this learning tool with the environmental, economic, and civic importance of brownfields and the toxification of the environment.

After the SENCER award, several grants that supported the development of BA also allowed project evaluators to gather assessment data using various methods with different groups of students over the years. Some of these include:

Critical Incident Reports

Critical incident reports, in which students wrote journal responses where they articulated a moment when they felt the simulation was useful and described (1) what they were trying to accomplish or understand, (2) how using the simulation helped and (3) what would have been different if they had been using more conventional instructional materials, found that all students in the group studied (*n*=28) who were specifically interested in science liked the simulation. Three quarters of the non–science Barnard students also reported using the simulation as an overall positive experience, suggesting that it made science accessible. The responses indicated that the affordances of BA (as perceived by the students) fall into three categories: BA is an important *visual aid* (twenty responses), helping them to visualize issues such as the spread of groundwater contamination; the *narrative* elements of BA help them understand the complex forces involved in understanding real life environmental problems (twenty-five responses); and, *interactivity* as a primary value of the simulation in their learning, noting the authenticity of doing everything, from interviewing residents, to reading news accounts, to making cost analyses of using the various technical tools, all to produce a real-life ESA (twenty-five responses); in addition, some separately noted that the authenticity made it fun as well (five responses). Visualization, the narrative element and interactivity are all important components of authenticity. Rosenbaum (2007) emphasized the importance of authenticity for simulations that provide real-life interactivity for problem-solving so that students learn to "work with incomplete information, adapt to changing conditions, manage complexity, and fluidly create and share knowledge." While BA does not use augmented reality on location with students as in the Rosenbaum study, there is some evidence from this survey that some authenticity goals can been achieved within the laboratory setting using simulations like BA.

Student Surveys

Examination of a student opinion survey of sixteen statements rated by forty students (the majority were Barnard non-science undergraduates) about the use of simulations in the classroom on a six-point scale revealed that the majority of students agreed that BA's complex narrative helped them see the multidisciplinary nature of the BA model from different perspectives. Most agreed the decisionmaking aspect was an enrichment of their learning experience. Some still preferred learning course content using traditional classroom materials, but most found the interactive element, the ability to explore by trying things out and having the opportunity to take individualized pathways through the material, useful. Many agreed that the simulation was helpful because they could explore and make mistakes without real consequences and that the narrative helped them imagine what this kind of decisionmaking might be like in real life. Students were unanimous in their rejection of the idea that educational simulations increase social isolation by having students interact with virtual rather than real people.

Student Reports

Finally, content analysis of the final ESA reports produced by a Barnard cohort (*n*=25) were compared to the grades they obtained for the class and the ways in which they discussed the use of the simulation in their learning. The portion of the ESA that was analyzed using a validated four-level coding scheme asked students to provide a scientific basis to support their hypothesis about the alleged contamination of groundwater, including a description of water table characteristics, direction of groundwater flow, sediment analysis, D'Arcy's Law, and other evidence from the site. Results showed a correlation between how students felt about using the simulation and the quality of their site reports; a weaker correlation also existed with their final grades.

■ ■ ■

There are, of course, limitations in the evaluation studies to date that will be addressed through further work. The conclusions brought forth in the most recent formative evaluation provide sound evidence for BA as an effective learning tool. However, some student resistance to nontraditional curricula in science courses that challenge them to learn a new way of learning (i.e. process and method over facts) continues to impact our results, especially when looking at student perceptions of learning. The BA team directly addresses this resistance in its faculty training sessions, suggesting strategies to help instructors be explicit and reflective with students about BA's approach. Also important to note is that even high-quality experienced faculty members must make multiple attempts to optimize the amount of guidance to use with BA for their particular audience. To that end, further evaluation with a larger sample size and increased data collection as more schools make use of the curriculum, and adjustments of evaluation instruments for more incisive findings, will likely lead to more conclusive positive learning outcomes.

Discussion

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: increased engagement; adaptations for students with high or low prior knowledge; effective replacement for expensive/impractical field trips; control over the pace and direction of learning; increase in student participation over large lecture hall formats; effectiveness in representing complex subject matter; application to realistic situations; and packaging of complex ideas into a consistent narrative. Much of the literature on computer-based simulations cited below is built upon the legacy of researchers such as Greenblat (1981), Lederman (1984), and Petranek (1992, 1994), who showed how paper-based educational simulations could motivate learners to be active participants in their own learning through individualized activities and immediate feedback. Many researchers are actively engaged in the study of particular teaching and learning strategies that employ a custom-created computer-based simulation or game similar to BA (Barab 2000, 2002, 2005; Dede and Ketlehut 2003; Rosenbaum et al. 2007; Kim et al. 2009; Jacobsen et al. 2009). And a number of researchers have explored the use of simulation technologies in creating virtual field trips as a response to educational, logistical and economic constraints (Arrowsmith et al. 2005; Whitelock and Jelfs 2005; Ramasundaram et al. 2005). Mayer and Chandler (2001) found that students who had more control over the pace and direction of educational simulations showed better learning outcomes than those who had less, or what Betrancourt (2005) has called the *interactivity principle*. Accordingly, engaging students with the educational content at hand is key. BA accomplishes this through the gradual unveiling of additional components as students learn more concepts and discover more of the town and its underlying hydrogeologic features. Student teams control the pace and direction of their explorations to varying degrees depending on the course level in which BA is implemented.

Some researchers suggest that using simulations and educational games can be an effective way to engage the "video game generation" (Katz 2000, Prensky 2006). Researchers in recent years have also found that the learning and engagement seen in young people's playing of video games, including simulation-based games, can be translated into meaningful educational gains in the classroom (Shaffer et al. 2005; Gee 2003; Rieber 2001, 2004, 2008; Prensky 2006; Herrington et al. 2007; Van Eck 2007; Chinn 2002). Simulations also allow the packaging of complex issues into consistent narratives, which can facilitate meaning-making (Bruner 2002; Weinberger et al. 2005). They have also been found to be an effective way to represent complex systems and explore multifaceted sociotechnical problems (Gee 2005; Squire and Jenkins 2004; Barab et al. 2005; Rosenbaum 2007; Herrington et al. 2007). Learners are able to understand educational content by exploring it within realistic situations, consistent with the principles of situated learning (Lave and Wenger 1991; Barsalou 1999; Pedretti 1999; Barab and Plucker 2002; Rosenberg 2006). Through its use of a complex narrative with interactive videos and maps as well as environmental testing tools and other game-based features, BA takes advantage of the motivational features of games to engage students in the narrative of an environmental contamination event that weaves in a system of scientific skills and concepts.

Simulations also allow educators to move away from large lecture halls, where students are typically passive, and increase participation through inquiry-based learning. However, the role of teachers in scripting and facilitating simulation-based activities remains crucial (Barab et al. 2000; Weinberger et al. 2005). While measurable benefits of educational simulations have been shown to vary according to prior knowledge, the medium has been shown to positively impact comprehension, cognitive load and learning efficiency (Park et al. 2009). BA is particularly adaptable to students with high and low prior knowledge because the nature and amount of assignments can be modified and because contextual help provided by instructors can be tailored to the appropriate level of the intended audience.

■ ■ ■

Technology can have powerful effects in putting constructivist principles into practice. A truly useful multimedia-supported learning environment must present the nuts and bolts of the discipline being taught, provide a realistic context in which those basic principles operate, and allow students to explore the forms, relations, and implications of the data they encounter. Most importantly, the simulation should embody a rich and complex narrative — ideally including conflicting threads of information to unravel and false leads to decode — in which students must solve substantive problems, occupy constructive roles, overcome hasty judgments, and resolve ambiguity. In BA, the level of complexity increases during the semester-long inquiry, giving rise to ambiguity. Because there is no set of fixed outcomes, ambiguity is a fundamental component of BA as well as real-world investigations. This crucial feature is absent in most traditional, well-designed, laboratory science exercises, which often take a "cookbook" approach to learning — that is, if the instructions are understood and followed, students know there is a solution that can be achieved before the end of the lab period. Awareness of this ambiguity is an important pedagogical tool as students try to reverse "cookbook" expectations, deal with the insecurity of ambiguity, and find threads that lead to real solutions.

Not surprisingly, the inquiry-based approach of BA produces conflicts with previously learned student behaviors that accompany traditional, didactic methods. For example, students often become frustrated when outcomes do not provide the immediate sensation of being done or with a clear sense of the end in sight. Furthermore, student work habits typically involve spikes of effort revolving around the next test or assignment. For continued success in BA, students must own, internalize, and utilize concepts and information beyond the next test or assignment. There are many paths to discovering the hidden reality embedded in the simulation, but, regardless of the path chosen, BA requires consistent and persistent effort without the stimulus of continuous due dates or deadlines. Students, thus, begin to also understand and own the process and difficulties of their own education.

BA is also exceptional in that it is designed to foster a respect for learning by placing students in a learning environment that insists that they gain ownership of the aptitudes for analysis, the competence in the demanding discipline of an environmental site assessment, the expertise to employ a variety of analytical methods to respond both critically and creatively to the simulation, and the ability to promote and advance the effectiveness of teamwork within the student companies. These pedagogical issues are raised with students directly both in lecture and laboratory in an effort to raise their awareness about their eventual transition to the challenges of life beyond the college classroom.

The BA laboratory experience also supports student learning. Lab sessions are designed to be seamless, integrated, and continuously evolving from one lab to the next, and because the BA simulation is network-based, student companies can continue their work during the week anywhere there is Internet connectivity. More importantly, laboratory exercises for BA are integrated into the simulation and, thus, need to be understood in the context of new information and reevaluated in the context of a final report to the development corporation. For example, a standard lab exercise involving the sieving of sediment and the determination of particle-size distributions and porosity becomes in BA an investigation of sediment from a drill hole at the abandoned factory. The porosity data from this analysis must be combined with permeability data determined in a subsequent laboratory and with an understanding of D'Arcy's Law to calculate groundwater velocity. This calculation is important for predicting and understanding the nature and extent of the contaminant plume but also for legal, forensic, and planning purposes. Thus, students must not only learn about particle-size distributions, porosity, permeability, and D'Arcy's Law but must also own this information in order to use it in the context of their investigation and final report.

Finally, BA is unique in that it accurately replicates a real-world experience for students. At the beginning of BA, students are told that their education will be defined by those aspects of the experience that they "own" and are able to use to influence their lives six months after the course is over. The problems posed in BA cannot be solved without the knowledge component, but BA puts content into motion as it is actually used in the real world. To succeed in BA, students must acquire and administer problem-solving skills associated with a range of activities and professional roles as:

1. *Journalists* or, students must assess the credibility of information provided by a cast of characters who have conflicting motivations and different levels of knowledge, navigating their way through a complex tableau of fragmentary information and partial truths.
2. *Environmental scientists and engineers*, students must study the relevant techniques, such as ground-penetrating radar and soil gas analysis, and use them judiciously.
3. *Business managers*, student companies must make decisions about the relative value of all available investigative procedures, complete their ESA, and maximize profit.
4. *Public health professionals,* students must investigate the possible medical consequences of a toxic event and assess and substantiate claims about a causal link between individual medical cases and the contamination.
5. *Citizen activists*, students must understand basic civics and the law and be politically savvy as they interpret public records, gather information for possible indictments, form recommendations about the steps required to remedy

environmental damage, and make decisions that reflect values associated with land use, private property rights, and public welfare.

This interdisciplinary approach represents a more practical and realistic picture of the utility of science in today's world. Because BA is an investigation of environmental contamination and takes place within a simulated city with actual people, the central theme of the semester is one of civic engagement. Brownfields, environmental site assessments, and toxification of the environment are of concern to everyone. The combination of the motivation of civic engagement with science in a realistic context allows BA to show how to "bridge the gap" between the "two cultures" and bring the scientific and non–scientific communities together (Burns and Holt 2009).

■ ■ ■

Those interested in exploring the simulation in more detail and learning how other instructors have utilized BA should visit brownfieldaction.org, and contact the site administrator to obtain a password.

About the Authors

Peter Bower, conservationist and educator, is a senior lecturer in the Department of Environmental Science at Barnard College/Columbia University, where he has taught for twenty-four years. He has been involved in research, conservation, and education in the Hudson River Valley for thirty years. He is the former Mayor of Teaneck, New Jersey, where he served on the City Council, Planning Board, and Environmental Commission for eight years. He received his B.S. in geology from Yale, M.A. in geology from Queens, and Ph.D. in geochemistry from Columbia. Contact: Barnard College, 3009 Broadway, New York, N.Y. 10027 pb119@columbia.edu, 212-854-3589.

Ryan Kelsey is the associate director for research and evaluation at the Columbia University Center for New Media Teaching and Learning and adjunct assistant professor at Teachers College and Columbia University. He has over ten years of experience at Columbia designing, implementing, and evaluating educational technology projects and consulting with faculty on best practices in teaching and learning. One of his specialties is the use of simulations in science and health. He received his B.S. in biology from Santa Clara University and his M.A. and Ed.D. from Teachers College in communication and education. Columbia University, CCNMTL, 2970 Broadway, Mail Code 4122, New York, NY 10027, ryan@columbia.edu, 212-854-0209

Frank Moretti has thirty-nine years of experience in school-based leadership and is recognized as one of America's leading theorists and practitioners in the use of digital technology in education. He was the executive director of the internationally known Dalton Technology Plan. He founded the software company Learn Technologies Interactive. He is currently the co-founder and executive director of the Columbia University Center for New Media Teaching and Learning and professor of communication and education at Teachers College, Columbia University. He received his Ph.D. in history from Columbia University. Columbia University, CCNMTL, 2970 Broadway, Mail Code 4122, New York, NY 10027, fmoretti@columbia.edu, 212-854-1692.

References

Arrowsmith, C., A. Counihan, and D. McGreevy. 2005. "Development of a Multi-scaled Virtual Field Trip for the Teaching and Learning of Geospatial Science." International Journal of Education and Development using ICT 1(3). ijedict.dec.uwi.edu/viewarticle.php?id=29 (accessed December 4th, 2009).

Barab, S.A., K.E. Hay, K. Squire, M. Barnett, R. Schmidt, K. Karrigan, L. Yamagata-Lynch, and C. Johnson. 2000. "Virtual Solar System Project: Learning Through a Technology-rich, Inquiry-based, Participatory Learning Environment." *Journal of Science Education and Technology,* 9(1): 7–25.

Barab, S.A., and J.A. Plucker. 2002. "Smart People or Smart Contexts? Cognition, Ability, and Talent Development in an age of Situated Approaches to Knowing and Learning." *Educational Psychologist* 37(3): 165–182.

Barab, S., M. Thomas, T. Dodge, R. Carteaux, and H. Tuzun. 2005. "Making Learning Fun: Quest Atlantis, a Game Without Guns." *Educational Technology Research and Development* 53(1): 86–107.

Barsalou, L.W. 1999. "Language Comprehension: Archival Memory or Preparation for Situated Action." *Discourse Processes* 28: 61–80.

Bereiter, C. 2002. "Design Research for Sustained Innovation." *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society* 9(3): 321–327.

Betrancourt, M. 2005. "The Animation and Interactivity Principles in Multimedia Learning." In *The Cambridge Handbook of Multimedia Learning,* R.E. Mayer, ed., 287–296. New York: Cambridge University Press.

Bruner, J. 2002. *Making Stories: Law, Literature, Life.* New York: Farrar, Straus and Giroux.

Burns, D., and R. Holt. 2009. "Citizen Science and Our Democracy." *Science Education and Civic Engagement* 2(1): 6–8.

Chinn, C.A., and B. Malhotra. 2002. "Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks." Science Education 86(2): 175–218.

Collins, A. 1992. "Toward a Design Science of Education." In *New Directions in Educational Technology*, E. Scanlon and T. O'Shea, eds., 15–22. Berlin: Springer-Verlag.

Edelson, D.C. 2002. "Design Research: What We Learn When We Engage in Design." *The Journal of the Learning Sciences* 11: 105–121.

Gee, J.P. 2003. *What Video Games Have to Teach us About Learning and Literacy*. New York: Palgrave Macmillan.

Gee, J. 2005. "Why Are Video Games Good for Learning?" www.academiccolab.org/resources/documents/MacArthur.pdf (accessed November 20, 2009).

Greenblat, C.S. 1981. Seeing Forests and Trees: Gaming-simulation and Contemporary Problems of Learning and Communication. In *Principles and Practices of Gaming Simulation*, C.S. Greenblat and R.D. Duke, eds., 13–18. Beverly Hills, CA: Sage.

Herrington, J., T.C. Reeves, and R. Oliver. 2007. "Immersive Learning Technologies: Realism and Online Authentic Learning." *Journal of Computing in Higher Education* 19(1): 80–99.

Jacobson, A.R., R. Militello, and P.C. Baveye, 2009. "Development of Computer-assisted Virtual Field Trips to Support Multidisciplinary Learning." *Computers and Education* 52(3): 571–580.

Katz, J. 2000. "Up, Up, Down, Down." slashdot.org/features/00/11/27/1648231.shtml (accessed November 25, 2009).

Kelsey, R. 2003. "Brownfield Action: An Education Through and Environmental Science Simulation Experience for Undergraduates." Ed.D. dissertation, Teachers College, Columbia University.

Kim, B., H. Park, and Y. Baek. 2009. "Not Just Fun, but Serious Strategies: Using Meta-cognitive Strategies in Game-based Learning." *Computers & Education* 52(4): 800–810.

Lave, J., and E. Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. New York: Cambridge University Press.

Lederman, L.C. 1984. "Debriefing: A Critical Reexamination of the Post-experience Analytic Process with Implications for its Effective Use." *Simulation and Games* 15(4): 415–431.

Mayer, R.E., and P. Chandler. 2001. "When Learning is Just a Click Away: Does Simple User Interaction Foster Deeper Understanding of Multimedia Messages?" *Journal of Educational Psychology* 93(2): 390–397.

Park, S.I., G. Lee, and M. Kim. 2009. "Do Students Benefit Equally from Interactive Computer Simulations Regardless of Prior Knowledge Levels?" *Computers & Education* 52(3): 649–655.

Pedretti, E. 1999. "Decision Making and STS Education: Exploring Scientific Knowledge and Social Responsibility in Schools and Science Centers Through an Issues-based Approach." *School Science and Mathematics* 99: 174–181.

Petranek, C., F. Corey, and R. Black. 1992. "Three Levels of Learning in Simulations: Participating, Debriefing, and Journal Writing." *Simulation & Gaming* 23: 174–185.

Petranek, C. 1994. "A Maturation in Experiential Learning: Principles of Simulation and Gaming." *Simulation & Gaming* 25(4): 513–523.

Prensky, M. 2006. *"Don't Bother Me, Mom, I'm Learning!" How Computer and Video Games are Preparing Your Kids for 21st-Century Success and How You Can Help!* St. Paul: Paragon House.

Ramasundaram, V., S. Grunwald, A. Mangeot, N.B. Comerford, and C.M. Bliss. 2005. "Development of an Environmental Virtual Field Laboratory." *Computers and Education* 45: 21–34.

Rieber, L.P. 2001. "Designing Learning Environments that Excite Serious Play." Paper presented at the annual meeting of the Australasian Society for Computers in Learning in Tertiary Education: Melbourne, Australia, December.

Rieber, L.P., S. Tzeng, and K. Tribble. 2004. "Discovery Learning, Representation, and Explanation within a Computer-based Simulation: Finding the Right Mix." *Learning and Instruction* 14(3): 307–323.

Rieber, L.P., and D. Noah. 2008. "Games, Simulations, and Visual Metaphors in Education: Antagonism Between Enjoyment and Learning." *Educational Media International* 45(2): 77–92.

Rosenbaum, E., E. Klopfer, and J. Perry. 2007. "On Location Learning: Authentic Applied Science with Networked Augmented Realities." *Journal of Science Education and Technology* 16(1): 31–45.

Rosenberg, M.J. 2006. *Beyond E-learning*. San Francisco: Pfeiffer.

Shaffer, D.W., and J.P. Gee. 2005. Before Every Child Is Left Behind: How Epistemic Games Can Solve the Coming Crisis in Education. WCER Working Paper no. 2005-7, Wisconsin Center for Education Research, School of Education, University of Wisconsin-Madison.

Squire, K., and H. Jenkins. 2004. "Harnessing the Power of Games in Education." *Insight* 3(1): 5–33.

Van Eck, R. 2007. "Six Ideas in Search of a Discipline." In *The Design and Use of Simulation Computer Games in Education*, B.E. Shelton and D.A. Wiley, eds., 31–60, Boston, MA: Sense Publishers.

Weinberger, A., B. Ertl, F. Fischer, and H. Mandl. 2005. "Epistemic and Social Scripts in Computer-supported Collaborative Learning." *Instructional Science* 33(1): 1–30.

Whitelock, D., and A. Jelfs. 2005. Would You Rather Collect Data in the Rain or Attend a Virtual Field Trip? Findings from a Series of Virtual Science Field Studies." *International Journal of Continuing Engineering Education and Lifelong Learning* 15(1/2): 121–131.

TEACHING & LEARNING

Environmental Release of Genetically Engineered Mosquitoes

Is It Safe? A Role Playing Activity for STEM Education

Abour H. Cherif
DeVry University

Farahnaz Movahedzadeh
Department of Biological Sciences, Harold Washington College

Linda Michel
DeVry University

Aaron Hill
Clinical Microbiology Lab, Virginia Commonwealth University Medical Center

Dianne M. Jedlicka
DeVry University

Introduction

There is agreement among educators that effective teaching helps students to think critically, communicate effectively, learn self-discipline, develop an understanding of oneself and others, and cultivate the perpetuation of self-education (Freiberg and Driscoll 2001; Cherif and Adams 1993). One effective technique that encourages such participation is role playing. Role playing provides an opportunity for "acting out" conflicts, collecting information about social issues, learning to take on the roles of others, and improving students' social skills. As a teaching approach, role playing is an indispensable part of human development; it offers a unique way to resolve interpersonal and social dilemmas (Joyce et.al. 2009), and is helpful in achieving learning objectives (Cherif and Somervill 1995; Ross et al. 2008). Role playing also provides an opportunity for students to engage in active learning which involves the critical analysis of new ideas by linking them to already known concepts or principles; something that could lead to better understanding as well as long-term retention of concepts (Houghton 2004). Additionally, it gives students the opportunity to tie together concepts from diverse fields such as molecular biology, medicine, public health, genetics, environmental protection/stewardship, and economics, promoting an interdisciplinary learning experience.

In this activity, groups of students assume the roles of representatives of the World Health Organization (WHO), Food and Drug Administration (FDA), Friends of the Earth (FOE) organization, the scientific community, a university research team, the biotechnology industry, and the media. The students work together to develop convincing arguments and debate whether or not to support the release of genetically engineered mosquitoes into the environment to provide a significant *immediate* benefit to society. In the process, the students learn and reinforce their understanding of the principles of DNA structure and replication, genetic mutations, genetic engineering, infectious diseases, insects and resistance to drugs and insecticides, public health, and environmental protection/stewardship. In addition, role playing activities such as this one provide an engaging opportunity to discuss conflicting views on scientific issues, and also demonstrate how technological advances and social, political and economic issues change the direction and nature of science, while exploring the moral, ethical and social dimensions of our society.

Background

Mosquitoes are an important public health concern due to their ability to transmit diseases. In many parts of the world, especially the tropics and subtropics, the rainy season is associated with protecting oneself from the bites of insects, including over 3,500 different species of mosquitoes. Mosquitoes have four complex life cycle stages: egg, larva, pupa, and adult or imago. Each of the four stages goes through a very different interaction with their environment. The first three stages are aquatic in nature, and the fourth is the flying adult. To start the life-cycle, adult females lay their eggs in standing water in which they hatch into larva and then the pupae forms before emerging as flying adults within five to fourteen days. The adult mosquitoes often live for Four to eight weeks.

The mosquito is a member of the family *Culicidae*, with unique features including mouthparts that are specialized for piercing the skin of plants and animals. While males typically feed on plant nectar, in some species of mosquitoes, the females can only produce eggs once they have obtained protein-rich hemoglobin from a blood meal. Their mouthparts allow an infected mosquito to deliver the pathogenic organisms it is carrying directly into the bloodstream of the animal or human it bites (see Appendix A). Because of this, mosquitoes are vectors for a number of infectious diseases, including malaria, which affect millions of people each year.

Malaria is one of humankind's oldest recorded maladies. Signs of malaria have been discovered in Egyptian mummies, and the detailed documentation of the distinctive stages of illness was found in Hippocrates's medical journal in the fifth century. (Carmichael 2010a; Finkel 2007; Postlethwait and Hopson, 2003). The emergence of a treatment for malaria has an interesting historical origin:

> In the mid-1600s, the natives of Lima, Peru, were already using bark from a tree in the Andean cloud forests to treat the disease. Spanish diplomats returned the bark to Europe, where it became known as quinine and remained the principal treatment until World War II, when researchers developed chloroquine and other synthetic substitutes. Unfortunately, resistance to multiple malaria drugs has evolved in many populations of the deadly protest *Plasmodium falciparum*. Their major hosts, Anopheles mosquitoes, also evolved resistances to DDT and other insecticides. As a result of this, the incidence of malaria began rising dramatically in the late 20th century. (Postlethwait and Hopson 2003, 295).

Malaria is transmitted by female mosquitoes of the *Anopheles* genus, the only insect capable of harboring the human malaria parasite *Plasmodium*. This single celled parasite is picked up by the female *Anopheles* mosquito from the blood of infected people and spread to uninfected people through a bite. (See Appendix A and B.) There are four types of human malaria: *Plasmodium vivax*, *P. malariae*, *P. ovale* and *P. falciparum*. *Plasmodium vivax* and *P. falciparum* are the most common forms. Among all of them, Falciparum malaria is the most deadly type with highest rates of complications and mortality. It is also the most common in sub-Saharan Africa where more than 75 percent of all cases occur, and where it causes nearly a million deaths a year (WHO 2008, 11–12; WHO 2010). Worldwide, about 300–500 million people in 106 countries get malaria each year. In some parts of the world, malaria is responsible for as many as half of all childhood deaths (Finkel 2007). Common symptoms are extreme chills with shivering, sweating, and fever. Infected individuals alternate between chills and fever and have an enlarged spleen; in addition, rapid breathing and profuse sweating can occur as the fever decreases (Tortora et. al 2007; Bauman 2006). (See Appendix B.) Malaria is not easily cleared by the human immune system. As stated by William (2010, 42), "malaria parasites invade human blood cells, they churn out a sticky protein that makes the blood cells clump together. This keeps the cells from reaching the spleen, where the immune system would destroy them, and gives the malaria parasite—*P. falciparum*—a safe haven inside the cells to replicate." (William 2010, 42)

If not treated promptly with effective medicines, the red blood cells of infected people will be destroyed and their capillaries which carry blood to the brain or other vital organs can be clogged, leading to a painful death. For many years people all over the world have battled malaria by fighting its carrier, the stubborn mosquito. Today, WHO, other governmental and private health organizations, and many scientists and medical doctors have been working very hard to control mosquitoes and develop vaccines and anti-malaria drugs as well as to improve the speed and rate of how the human immune system responds to the parasite. However, both mosquitoes and *Plasmodium* have evolved resistance to the insecticides and drugs that scientists have developed to combat them and prevent the occurrence of malaria among human population. (See Appendix C and D for prevention and for current treatment and drugs used to treat malaria.) Effective vaccines have yet to be developed against malaria, due to the parasite's ability to escape the host immune response. However, some hope is emerging in the vaccine research field. In "Halting the World's Most Lethal Parasite," Mary Carmichael (2010a, 69) writes:

> Right now, somewhere in the world—in a petri dish in Baltimore, maybe, or in the salivary glands of a laboratory-bred mosquito in Seattle, or in the bloodstream of a villager in Ghana—resides a chemical compound that could help eradicate human history's biggest killer. Scientists have many promising malaria vaccine candidates in the works, and for the first time one have reached advanced human trials. If it or another candidate is even partly effective in people, it could save the lives of millions of children and pregnant women. It would be the only vaccine yet developed against a human parasite, an achievement of Nobel caliber.

If we could find an effective way to battle malaria, millions of lives could be saved each year. A group of scientists at the University of Arizona has turned to genetic engineering for a solution. In July 2010, the research team altered some of the genetic codes in female *Anopheles* mosquitoes, in hopes of developing a mosquito that is resistant to *Plasmodium*. It has been reported by Schneiderman (2010, 8):

> They [scientists] performed the trick by altering the bug's DNA making it 100 percent resistant to the disease and shortening its life span enough to stymie the growth of malarial parasites. The next step would be to give this malaria-proof insect an evolutionary edge and release it into the wild, where it can conquer the world's existing mosquito species. It would take more than a decade before this idea is ready to be implemented. But the hand-wringing has already begun.
>
> Scientists have never played God in such a way, replacing a natural species with one of their own creation. "We don't know the long-term effects", say Eric Hoffman, a campaigner at Friends of the Earth, which opposes genetically modified organisms. The World Health Organization intends to devise rules for testing genetically modified mosquitoes to ensure, among other things, that the bug's altered DNA doesn't make it a better carrier of other diseases.

These developments may someday help fight insect-borne infectious diseases without the need for insecticide and significantly improve the quality of life for millions of people. Michael Riehle, an entomologist who led the University of Arizonian research, says, "Hopefully the benefits will outweigh the risks" (Schneiderman 2010, 8). But, using Mark Skinne's (2010) words in a different context, should science dictate policy or policy dictate science? This statement becomes the premise for this activity.

Learning Activity

The objective of this leaning activity is to help students understand the principles of DNA structure and replication, genetic mutations, genetic engineering, infectious diseases, insects, and drug and insecticide resistance through understanding and debating the role of genetic engineering in biological diversity, environmental protection/stewardship and sustainability, and the enhancing of life and living in human societies.

To begin, each group of students selects a committee to represent and design convincing arguments that either support or oppose genetic engineering of the DNA of the female mosquito. The genetic changes are meant to make mosquitoes resistant to infection by *Plasmodium*, thereby helping to prevent the occurrence of malaria among the world's populations. The long term effects of releasing genetically engineered mosquitoes into the environment are unknown.

To ensure that the students research the proper references and that the debate is conducted between very well informed groups, all the students are asked to read the following articles as the starting point of their own research:

- Carmichael 2010a;
- Dunavan 2010;
- Finkel 2007;
- Judson 2003;
- Koening 2010.
- Marsa 2010;
- Perry 2010; and
- WHO report, current issue.

After the initial presentation of information by the instructor, the students are given time to work together and collect additional information necessary to design and develop a plan. They then "act out" that plan by successfully arguing in favor of or against genetically engineering the DNA of the female mosquitoes. This role-playing activity can last two hours to two weeks, including preparation and presentation time.

Through role-playing and classroom debates, students gain the following: They learn to make choices, organize their information, and take on roles; they improve their social skills and academic performance; and they learn and reinforce their understanding of the principles of DNA structure and replication, genetic mutations, genetic engineering, infectious diseases, insects and drug resistance, the roles of insects such as mosquitoes in the environment including biological diversity and environmental sustainability.

Procedures

Before presentations, implement the following procedures.

1. Form a debate committee that consists of the instructor of the class, another instructor from the school, and one or two academically respected students from the same class.
2. Divide the students into groups of two or three and randomly ask each group to select one of the communities to represent: World Health Organization, Food and Drug Administration, Friends of the Earth, the scientific community, a university research team, the biotechnology industry, or the media.
3. Allow the groups to inform each other of their selections, as well as to exchange selections if they wish. This will make the groups more committed to their selections.
4. Give the students two to three weeks (time can be shortened or lengthened) to prepare for the debate, and inform the groups to complete the following steps (a–e):
   a. Read all the eight reading assignments before starting their own research. This will ensure that all the students at least are exposed to the same level and type of information before the debate.
   b. Research and prepare a well-informed paper, based on their own group's perspective, to support or oppose genetically engineering and releasing mosquitoes into the environment despite the fact that the long-term effects on its own species and on the surrounding environment are unknown.
   c. Be well prepared to engage in a meaningful debate to convince their classmates that their perspective is the one that should be adopted.
   d. Have a well-researched handout to be distributed to the class before the presentation, as well as an illustrated poster, poems, songs, cartoons, etc. that can help convey the group's message and support its argument and perspective.
   e. Integrate the use of technology in their presentation, such as the use of PowerPoint, animations, interactive activities, as well as songs/poems, etc. to present their plan and strategy to show how and why their perspective should be adopted.
5. At every class meeting, make sure that students are working on their assignments. For example, give 15–30 minutes to the members of each group at the end of the class meeting to sit together and reflect on the progress they have made.
6. Finally, remind each group of students that they must have a good grasp of their point of view, as well as an understanding of the opinions of the other communities: "Those who do not completely understand their adversary's point of view do not fully understand their own" (Bender 1986, 9). In addition, also remind them that the objectives in this role-playing activity are to help them develop:
   a. Team work and communication skills.
   b. Critical thinking and problem-solving skills.
   c. Breadth and depth of concepts and vocabulary of biotechnology and their application to life in our contemporary technological society.
   d. An understanding of the social, economic and environmental implications and limitations of science, technology, and genetic engineering.
   e. An awareness of their own attitudes, feelings and values and how they differ from others.
   f. An awareness of the importance of biological diversity in environmental protection/stewardship, economy and sustainability.

During presentations, implement the following procedures

1. The groups take turns presenting their perspectives. The debate committee questions each group. In addition, the students in the class can ask up to three questions after a group finishes its presentation. The members of each group take note of all the questions that are asked.

2. When all the groups have presented, the members of the debate committee can ask more questions to all the groups. The students can also ask questions, which the members of the debate committee may consider in their final judgment and decision.
3. The members of the debate committee wait until the next class meeting before sharing their final decision with the groups. During this time, if there is room in the school, the posters, illustrations, and poems, etc. can be made available for all the students to view.

After presentations, implement the following procedures

1. In making their final decision, the members of the debate committee take into consideration the following (a–d).
   a. The academic quality and integrity of the written paper, the oral presentation, the poster illustration, and/or any additional aids used by the students to convey their message.
   b. Clear evidence that the members of a given group conducted research beyond the 8 articles assigned by the instructor for all the students as reading assignments.
   c. The delivery of the presentation, the articulation of the perspective and arguments, the demonstration of the long term and short term effects, and the individual's personal involvement and engagement during the debate.
   d. The type and quality of questions asked during the debate. In addition, the quality of the answers the group provided to questions directed at them. Teachers and instructors can refer to Cherif et al. (2009) for useful tools and techniques that can be used to monitor the level of cognitive involvement of the members of a given group during the activity as well as to record the types of questions being asked by the members of a group, the relevance of the questions to the subject matter and to the point being debated, and the number of questions asked by the members of each group. (See Tables 1, 2 and 3 on the following page.)
2. Each group is given 2–3 minutes to address the debate committee one more time before the members of the committee read the final decision. In this short final remark, the groups must have a written statement that can be read to support their case.
3. After all the groups present their final remarks; a representative of the debate committee reads and defends the committee's final decision.
4. The instructor of the class must reinforce the principles of DNA structure and replication, genetic mutations, genetic engineering, infectious diseases, insects, and resistance to drugs and insecticides. He or she must also discuss the role of insects in biological diversity and environmental sustainability as well as the public health importance of mosquitoes from nuisance to disease.

Appendix E provides additional discussion topics on the theme of mosquitoes and malaria.

Assessment

In assessing students' performance and understanding, as well as the effectiveness of these activities, we have been using McCormack and Yager's (1989) taxonomy for science education as a framework for student achievement. A summary of this taxonomy can be found in Cherif et al. (2009). In the same article, teachers and instructors can also find useful tools and techniques for monitoring the level of cognitive involvement of the members of a group during the activity and recording the types of questions being asked by the members of a group, the relevance of the questions to the subject matter and to the point being debated, and the number of questions being asked by the members of each group. See Tables 1–3.

Conclusion

In this learning activity, we have tried to create a strategy of role playing that enables students to become more actively involved in learning about genetically modified organisms and their role in human life. In doing so, they learn about DNA structure and replication, genetic engineering, infectious diseases, insects and drug and insecticide resistance. Choosing a stance, either for or against releasing genetically engineered female mosquitoes into the environment, and debating that opinion among classmates improves student's communication, collaboration, and critical-thinking skills, and it enables them to have fun and enjoy learning.

The activity can be conducted before or after the topic is covered in class. In both cases, the wrap-up or ending discussion is important because it drives home the importance that

TABLE 1. Individual Group Questions Analysis and Account*

	Type of Question or Conditional Statement	Extremely Relevant	Relevant	Less Relevant	Not Relevant	Total Number of Questions
1	Why					
2	How					
3	What do you think if . . . ?					
4	Which					
5	What					
6	When					
7	Where					
8	Is/Are					
	Total number of questions and/or wondering statements					

* From Cherif et.al., 2009, 350.

TABLE 2. Tracking the Number of Question Asked by Each Group of Other Groups*

	WHO	FDA	Scientific Community	UA Research Team	Friends of the Earth	Biotech Community	Media
WHO	X						
FDA		X					
Scientific Community			X				
UA Research Team				X			
Friends of the Earth					X		
Biotech community						X	
Media							X
Total of Questions							

*From Cherif et.al, 2009, 351.

NOTE: WHO = World Health Organization; FDA = Food and Drug Administration; UA = University of Arizona

TABLE 3. Type of Questions or Conditional Statements and Their Values for Assessment Purposes

	Type of Question	Extremely Relevant			Relevant			Less Relevant			Not Relevant			TOTAL
		Number	Value Per	Total Values	Number	Value Per	Total Values	Number	Value Per	Total Values	Number	Value Per	Total Values	
1	Why, How		5			4			3			1		
2	What do you think if . . . ?		4			3			2			1		
3	Which		3			2			1			0.5		
4	What, When, Where		2			1			0.5			0		
5	Is, Are		1			0.5			0			0		
	Total													

DNA and genetic engineering have in our lives. In our case, this role-playing activity has benefited some of our students by motivating them to engage in deep learning that results in a meaningful understanding of material and content as well as long-term retention of learned concepts.

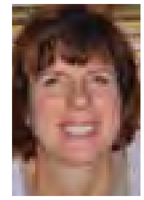
Acknowledgements

We would like to acknowledge the help of the reviewers and the editorial staff of the Science Education and Civic Engagement: An International Journal for their valuable suggestions and recommendations that made this paper more effective. Indeed, we have borrowed a few phrases from the reviewers' comments and feedback to integrate to the final version of this paper. We would also like to thank and acknowledge all those colleagues who read the paper and/or tried the activity in their classrooms and provided us with very valuable feedback. We are very grateful for the assistance.

About the Authors

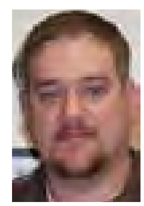
Dr. Abour H. Cherif (acherif@devry.edu) is the national associate dean of curriculum for math and science, and clinical laboratory sciences at DeVry University Home Office, Downers Grove, IL. He is past president (2008–2009) of the American Association of University Administration (AAUA). He holds a B.S. from Tripoli University, an MS.T. from Portland State University, and a Ph.D. From Simon Fraser University, Canada. Dr. Cherif's professional work includes curriculum design, development and reform, instructional and assessment design, evaluation techniques, faculty, and academic leadership. He has published more than fifteen science lab kits, a number of student laboratory manuals, co-authored and coedited a number of science textbooks, and published many articles in professional journals and newspapers. He has received a number of teaching, curriculum development, instructional strategies, and leadership awards. Dr. Cherif serves on the executive and or advisory boards of a number of organizations, including the International Institute of Human Factor Development (IIHFD) and the AAUA.

Farahnaz Movahedzadeh (fmovahedzadeh@ccc.edu) is a faculty member of Department of Biological Sciences at Harold Washington College in Chicago, Illinois. Farah received her Ph.D. from the University of London in 1997 in microbiology/molecular biology. Her current research interest includes the pedagogical effectiveness of blended/hybrid delivery method of learning in biology courses for non-science majors. She also actively pursues her research on essential genes as drug targets for tuberculosis at the University of Illinois at Chicago.



Linda Michel (lmichel@devry.edu) is visiting professor and science curriculum developer at DeVry University. She received her Ph.D. in Microbiology from Michigan State University. Dr. Michel is also co-editor of a number of textbook, lab books, and student study guides in general biology, microbiology, and chemistry. She has been teaching college-level biology, chemistry and microbiology courses online for a number of years.

Dianne Jedlicka has been teaching college-level biology courses to premed students, nursing students, and nonmajors for over 15 years. She uses real-life applications in her lectures, including examples from her background as a zoo education director and collections manager at the Field Museum of Natural History in Chicago and as a field ecologist and researcher. She is a visiting professor and science curriculum developer at DeVry University as well as professor of biology at the School of the Art Institute of Chicago and Columbia College, Chicago.



Aaron Hill, BS, MT (American Society for Clinical Pathology), is a supervisor in the Clinical Microbiology Lab at Virginia Commonwealth University (VCU) Medical Center in Richmond, Virginia. The 779-bed VCU Medical Center is a regional referral center for the state and the region's only Level I Trauma Center.

Appendix A: It Begins with a Painless Bite

The female *Anopheles* mosquito is the only insect capable of harboring the human malaria parasite *Plasmodium*. The mosquito's proboscis is made of highly specialized separate tools including cutting blades and a feeding tube powered by two tiny pumps.

> She [anopheles female] drills through the epidermis, then through a thin layer of fat, then into the network of blood-filled micro-capillaries. She starts to drink. To inhibit the blood from coagulation, the mosquito oils the bit area with a spray of saliva. This is when it happens. Carried in the mosquito' salivary glands—and entering the body with the lubricating squirt—are minute, worm-like creatures. These are the one-celled malaria parasites, known as plasmodia. Fifty thousand of them could swim in a pool the size of the period at the end of this sentence.

> Typically a couple of dozen slip into the bloodstream. But it takes just one. A single plasmodium is enough to kill a person. The parasites remain in the bloodstream for only a few minutes. They ride the flume of the circulatory system to the liver. There they stop. Each plasmodium burrows into a different liver cell. Almost certainly, the person who has been bitten hardly stirs from sleep. And for the next week or two, there's no overt sign that something in the body has just gone horribly wrong. (Finkel 2007, 40–41)

Appendix B: Mosquito Bites

Mosquitoes are most active at dawn or at dusk and that is the time when most people who are outdoors or in unprotected areas often get bitten by the hungry mosquitoes. Mosquitoes are attracted to the odor of human's skin and the carbon dioxide in human breath. If it is not for the protein-rich hemoglobin in our blood and the special odor of our skin, female mosquitoes might not even bother by biting us.

Mosquito bites are not only annoying, but they also have a high potential for transmitting serious diseases, such as West Nile virus, malaria and dengue fever. People may not feel or see any sign of being bitten by female mosquitoes simply because the signs and the symptoms of the bites may not show up for a few days depends on how sensitive a given person is to mosquito bites. The redness, swelling, and itching commonly noticed after a bite are actually caused by an allergic reaction. If such symptoms followed with fever, severe headache, body aches, nausea, vomiting, rash, sensitivity to light, and or neurological changes, etc., then, an individual must seek medical attention immediately.

While female mosquitoes are sucking blood, they deposit some of their saliva into the patients' skin. This type of saliva contains proteins called that remain in the victim's skin. In people who react to mosquito bites, special immune cells known as mast cells release histamine, a protein that causes itching and swelling. Although they itch, you should avoid scratching mosquito bites. According to Dr. Hema Sundaram, a dermatologist from Washington, D.C., when you scratch a mosquito bite, it stimulates your body to produce more histamine, causing even more itching (Deardorff, 2010, ¶. 2) Furthermore, scratching the mosquito bites causes skin injuries that often compromise the skin defense barrier. This could provide a golden opportunity for secondary bacterial infection to be caused with those bacteria that are naturally live on our skin and or in the environment.

Appendix C: Prevention of Malaria

While there is no way of preventing malaria that is 100 percent effective, prevention as well as protection techniques, tools, and treatments for malaria are evolving. Travel agencies, embassies, and medical agencies all provide up to date information about the best malaria protection for travelers and their citizens. According to the Health Central Network (2010) prevention should be based on:

- Evaluating the risk of exposure to infection;
- Preventing mosquito bites by using DEET mosquito repellant, bed nets, and clothing that covers most of the body; and
- Chemoprophylaxis (preventive medications).

The Health Central Network (2010) also lists questions to ask your doctor about malaria:

- Are preventive measures necessary for the region of the world I'll be visiting?
- Is this a high-risk area for malaria?
- What drugs can be taken as a preventive measure?
- What is the correct dosage?
- When should the drug be started and stopped?
- What other precautions should I take; repellents, clothes, nets?
- What symptoms should I look for?

Appendix D: Current Drugs Used To Treat Malaria Patients

Because malaria is a serious disease, a doctor should be consulted if patients are experiencing malaria symptoms such as a severe and pounding headache inside the skull, a high fever and chills. Malaria may be confirmed through a blood test and will likely be able to be confirmed through a noninvasive saliva test in the future (Wilson, Adjei, Anderson, Baidoo, and Stiles, 2008, 733). If the test is positive, medical personnel will determine the treatment plan most appropriate for infected individuals. Treatment is decided based on several factors including the geographical region in which the infected individual lives, the species of the parasite, different stages of the parasite's life cycle, the condition in which the infected person in, and sometimes, the age of the individuals.

Historically speaking, especially in sub-Saharan Africa, the classical treatment was quinine, which is really "nasty, bitter stuff that makes you urinate and makes your ears ring" (Postlethwait and Hopson, 2003, 277). Quinine remained the principle treatment worldwide until World War II, when researchers developed chloroquine and other synthetic substitutes. According to the Health Central Network (2010), today, the most prescribed drugs for treatment malaria patients include, "chloroquine, mefloquine, primaquine, quinine, pyrimethamine-sulfadoxine (Fansidar), doxycycline", artemisinin, to name a few. Unfortunately however, the deadly *Plasmodium falciparum* has already developed resistance to chloroquine (which is one of the most commonly used to treat it), and even it has started to develop resistance to the newer drug, artemisinin (Carmichael 2010b). People should be aware that there is no prophylactic regimen that gives complete protection against the disease. *Plasmodium* are constantly developing resistance to medications and additionally, they may produce more than one variation of the sticky protein at a time which makes infected red blood cells even stickier thus clumping together faster and tighter. This "keeps the cells from reaching the spleen, where the immune system would destroy, and gives the malaria parasite—*Plasmodium falciparum*—a safe haven inside the cells to replicate." (William 2010, 42)

Appendix E: Student Activities

This appendix contains other student activities on the theme of mosquitoes and malaria.

Activity: Malaria and HIV: Should We Really Be Concerned?

With malaria threatening half the world's population, and with *Plasmodium* developing resistance to almost every drug that was created to fight it, Michael Finkel (2010, 41) seems to be right by claiming that "we live on a malarious planet." Furthermore, in his book *A Short History of Nearly Everything,* Bill Bryson (2003, 312) writes:

> [M]any grade-A diseases—malaria, yellow fever, dengue fever, encephalitis, and a hundred or so other less celebrated but often rapacious maladies—begin with a mosquito bite. It is a fortunate fluke for us that HIV, the AIDS agent, isn't among them—at least not yet. Any HIV the mosquito sucks up on its travels is dissolved by the mosquito's own metabolism. When the day comes that the virus mutates its way around this, we may be in real trouble.

Conduct an Internet research to find out why Bill Bryson is very concerned about the possibility of the HIV virus mutating its way around the mosquito's own metabolism. Is there a relationship between what Bryson is talking about and what Finkel claims?

Activity: Sickle Cell Anemia, Thalassaemia, and Malaria

Conduct a literature search on sickle cell anemia and thalassaemia to find out:

1. What type of diseases are these?
2. How are they similar and how do they differ?
3. Why do these diseases occur in some places and not others?
4. Where are these two diseases most common?
5. What is (are) the common treatment(s) for both of them?
6. What is the relationship between these two diseases and malaria?

Activity: Planned Eradication of Species to Prevent Diseases

Out of 3,500 known species of mosquitoes worldwide, only about 30 species cause serious diseases to humans. These diseases include malaria, which is spread by Anopheles mosquitoes and dengue fever, yellow fever, and elephantiasis which are spread by Aedes mosquitoes. Recently, a number of scientists have been advocating the idea of eradicating mosquitoes that cause serious diseases to human would not lead to serious consequences in any ecosystem. Indeed, not only it would save the lives of millions of people, but also, for example, more than $12 billion in lost growth every year in African countries and hundreds of millions of dollars spent every year on mosquito control in the United States. Because of this, those scientists are supporting planned extinction of those species that have causing serious diseases. Indeed, this type of thought and techniques are not a new.

> Humans have aggressively worked toward the extinction of many species of viruses and bacteria in the cause of disease eradication. For example, the smallpox virus is now extinct in the wild—although samples are retained in laboratory settings, and the polio virus is now confined to small parts of the world as a result of human efforts to prevent the disease it causes (Wikipedia 2010)

In her article, "A Bug's Death", Olivia Judson has advocated the idea of "specicide," the planned extinction of an entire species that causes serious diseases. Even though it has never been tried before, Judson's idea is a simple and straightforward concept.

> Specicide . . . could be engineered by exploiting the biology of selfish genetic elements . . . which contribute nothing to the well-being of their hosts, but simply proliferate themselves. . . . As a result, a selfish genetic element can spread through a population extremely fast—far faster than a regular gene—even if it is harmful to its host. . . . [Therefore] to engineer extinction, devise an extinction gene—a selfish genetic element that has a strongly detrimental effect. The element could, for example, be designed to put itself into the middle of an essential gene and thereby render it useless, creating what geneticists call a ''knockout.'' If the knockout is recessive (with one copy of it you're alive and well, but with two you're dead), it could spread through, and then extinguish, a species in fewer than twenty generations. (Judson 2003, 2–3)

Given the fact that species become extinct "all the time" and anti-malarial and mosquito control programs all over the world offer little realistic hope to the 300 million people in developing nations who will be infected with acute illnesses every year, this does not seem to be a bad idea. While Judson couldn't predict the possible risks including ecological collapse and genetic escape, she believes that the proposed extinction technology "could eradicate the malaria mosquito, and malaria with it, within 10 years of the time mosquitoes modified to carry an extinction gene are released into the wild" (Judson 2003, 6). She adds, "Ideally, malaria would be defeated in other ways. Uganda has recently reported a 50 percent drop in death rates as a result of handing out free malaria medicines; if the program can be emulated and the trend sustained, perhaps by the time the technology is ready, it will no longer be needed. But if, by then, the situation is not much improved, we should consider the ultimate swatting." (Judson 2003, 13)

1. After reading Judson's article, compare the ecological collapse and the genetic escape as possible risks for planned extinction of misquotes that cause deadly illness to humans.
2. Do you agree with the idea of planned extinction of a species to prevent serious diseases?
3. If you were to write a letter to Olivia Judson what would you write and why?
4. Compare and contrast genetic modification (engineering) as a tool of creation and as a tool of extinction.
5. If you have to select one over the other in supporting biological diversity, environmental sustainability, and better life and living for human societies, which one of the two mechanisms in question 3 would you select? Explain.

Activity: Controlling the Mosquitoes:

Conduct research on mosquito's control to find out answers to the following questions.

1. What are some common strategies for controlling mosquitoes?
2. What compounds or chemicals are commonly are used for controlling mosquitoes?
3. How effective are they and what are some concerns about them?
4. What research is being conducted in mosquito control in terms of pesticides and application methods?

Discussion Questions

1. Why do scientists still have a hard time developing an effective vaccine against malaria?

2. Although all four species of *Plasmodium* can be deadly, why is *P. falciparum* particularly dangerous and more likely to be fatal than the others?
3. During which of these phases of the life cycle of *Plasmodium* (exoerythroeytic, erythrocyte, and sporogonic) can malaria be diagnosed from a human blood sample?
4. In your research, did you encounter other methods for diagnosing the presence of the parasite *Plasmodium* in human and or mosquitoes?
5. During mosquito seasons, many people get bitten and develop red bumps on their skin. Conduct literature research to find out and then come to class ready to discuss:
   a. Why do some people develop red bumps from mosquito bites and some others don't?
   b. Why do doctors advise us not to scratch mosquito bites?
   c. What will happen when you scratch the red bumps from mosquito bites? What are the consequences of this?
   d. What is the best way to avoid scratching your red bumps from mosquito bites?
   e. What do mosquito bites make the body skin cells do to produce the red bumps on the skin?
   f. What chemical(s) is(are) used in heart conditions that is similar to mosquito secretions?
6. What may happen if the bacteria that naturally occur on various areas of our body such as the skin or intestines gain entry into another area of the body? For example, what can happen if bacteria that normally live on the skin gain entrance to the bloodstream through a cut?
7. Since 1994 the Bill & Melinda Gates Foundation has been working to find ways to prevent and treat malaria. What techniques are they using in their fight to eradicate this disease?
8. What are the three most promising vaccine strategies to fight malaria? Explain how they work.
9. Given the fact that million people die every year from malaria worldwide, can you envision ways to speed up the distribution of an effective vaccine once one is found?
10. Discuss the public health importance of mosquitoes from nuisance to disease.
11. Discuss how geography and poverty are influence factors in the distribution of malaria.

Homework Assignment

To reinforce the learning objectives of the activity, ask students to answer the following questions, either individually or in groups (give them a time limit, such as 10 minutes or until the next class meeting).

1. Reflect on the final decision made by the members of the debate committee. Do you agree with it? Why or why not?
2. What have you learned from the activity, academically and personally?
3. If you had to do this all over again, what would you change, discard, or add? Why?
4. What advice would you give to public officials after your role playing experiences? (Freiberg and Driscoll, 2001, 347)
5. Evaluate the strengths of each presentation including your own group's and comment on the effect the arguments of others had on your consideration of the issue.
6. Did you initially agree or disagree with the point you were arguing for or against? Did your perspective change over the course of the activity?

References

Bauman, R. 2006. *Microbiology*. San Francisco: Benjamin Cummings.

Bender, D. 1986. "Why Consider Opposing Viewpoints." In *The Environmental Crisis. Opposing Viewpoints Series,* J.S. Bach and L. Hall eds., St. Paul, MN: Greenhaven Press.

Bryson, B. 2003. *A Short History of Nearly Everything.* New York: Broadway Books.

Carmichael, M. 2010a. "Halting the World's Most Lethal Parasite". *Scientific American*, 303(5):68–73.

Carmichael, M. 2010b. Pinning down a deadly shape shifter. *Scientific American*, 303(6):21.

Cherif, A.H. and G. Adams. 1993. "The Essence of Teaching." *Forward to Excellence in Teaching and Learning*, 1(1): 5–7

Cherif, A., L. Michel, F. Movahedzadeh, J. Siuda, G. Adams, and R. Aron. 2010. "Reinforcing the Importance of Hypotheses in the Scientific Method of Inquiry: A Learning Activity Using the 2006 Spinach Contamination Event." *Washington Science Teachers' Journal* 51(1): 34–40.

Cherif, A.H., L. Michel, F. Movahedzadeh, R. Aron, G. Adams, and S. Jenkins. 2009. "Defending the Lowly Prokaryotes: New Challenges for BIOGaia Leaning Activity." *American Biology Teacher* 71: 346–353.

Cherif, A.H., and C. Somervill. 1995. "Maximizing Learning: Using Role Playing in the Classroom." *American Biology Teacher* 57: 28–32.

Deardorff, J. 2010. "Why Can't I Scratch My Mosquito Bites?" *thespec.com (The Hamilton Spectator)*, Thurs., Aug. 19, 2010. www.thespec.com/living/healthfitness/article/250132--why-can-t-i-scratch-my-mosquito-bites (accessed December 23, 2010).

Finkel, M. 2007. "Raging Malaria: Bedlam in the Blood." *National Geographic*, 212(1): 32–67

Freiberg, H.J., and A. Driscoll. 2001. *Universal Teaching Strategies*. 3th ed. Boston: Allyn & Bacon

Health Central Network 2010. "Treatment of Malaria." www.healthscout.com/ency/68/347/main.html (accessed December 23, 2010).

Houghton, W. 2004. "How Can Learning and Teaching Theory Assist Engineering Academics?" *Higher Education Academy Engineering Subject Centre.* www.engsc.ac.uk/er/theory/learning.asp (accessed December 23, 2010).

Koening, R. 2010. "Piercing the Multi-Faceted Coat." *HHMI Bulletin* 23(4): 20–23

Judson, O. 2003. "A Bug's Death." *The New York Times*, September 25, 2003. www.nytimes.com/2003/09/25/opinion/a-bug-s-death.html (accessed December 23, 2010).

Joyce, B., M. Weil, and E. Calhoun. 2009. *Models of Teaching,* 8th ed. Boston: Pearson Education/Allyn & Bacon.

Marsa, L. 2010. "The Hot Zone: How We'll Stop the Coming Plague." *Discover,* Dec. 2010: 38–44.

McCormack, A.J., and R.E. Yager. 1989. "Toward a Taxonomy for Science Education." *B.C. Catalyst*, 33(1): 16–17.

Perry, A. 2010. "Global Health: Health Checkup—Malaria." *Time Health*, June 21, 2010: 37–46.

Postlethwait, J., and J. Hopson. 2003. *Explore Life*. Pacific Grove, CA: Brooks/Cole Thomason Learning.

Ross, W. 2010. "Hard Living Breeds Superbugs." *Discover*, Sept. 2010: 21.

Ross, P.M., D.A. Tronson, and R.J. Ritchie. 2008. "Increasing Conceptual Understanding of Glycolysis and the Krebs Cycle Using Role-Play." *The American Biology Teacher*, 70(3): 163–168

Rowland, J. 1958. *The Mosquito Man: The Story of Sir Ronald Ross*. New York: Roy Publishers.

Rudin, N. 1997. *Dictionary of Modern Biology*. Hauppauge, NY: Barron's Educational Series.

Schneiderman, R.M. 2010. "Scope—Nationalist: God Lives in a Lab in Arizona." *Newsweek*, Aug. 9, 2010: 8.

Skinner, M. 2010. "Science Should Dictate Policy." *US News & World Report*, Aug. 2010: 10.

Stein, R.A. 2010. "Human Activities and the Emergence of Pathogens." *American Biology Teacher* 72(8): 475

Tortora, G.J., B.R. Funke, and C.L. Case. 2007. *Microbiology: An Introduction*. 9th ed. San Francisco, CA: Benjamin Cummings.

Wikipedia 2010. "Extinction." en.wikipedia.org/wiki/Extinction (accessed December 23, 2010).

Wikipedia 2010. "Planned Extinction." en.wikipedia.org/wiki/Extinction#Planned_extinction (accessed December 23, 2010).

Williams, S. 2010. "In Brief: Malaria's Sticky Strategy." *HHMI Bulletin* 23(4): 42.

Wilson, N.O., A.A. Adjei, W. Anderson, S. Baidoo, and J.K. Stiles. 2008. "Detection of *Plasmodium falciparum* Histidine-rich Protein II in Saliva of Malaria Patients." *American Journal of Tropical Medicine Hygine*, 78(5): 733–735.

World Health Organization (WHO). 2010. Do All Mosquitoes Transmit Malaria? www.who.int/features/qa/10/en/index.html (accessed December 23, 2010).

World Health Organization (WHO). 2008. *World Malaria Report*. whqlibdoc.who.int/publications/2008/9789241563697_eng.pdf (accessed December 23, 2010).

RESEARCH ARTICLE

Feminist Interventions in Less than Feminist Spaces

Applying Feminist Pedagogies to the Large, Non-Majors Science Classroom

J. Kasi Jackson
Center for Women's Studies,
West Virginia University

Jane Caldwell
Department of Biology
Washington and Jefferson College

Introduction

> In my Biology 101 class, we've spent weeks studying DNA transcription, chromosome duplication and the like. We've spent weeks on it, yet, . . . we aren't going to be geneticists, and it's all just empty facts that we've learned but can do nothing with. . . . There are segues into global warming and touches on evolutionary theory, but mostly, it's plod ahead, get this over with. (Rivard 2006).

The preceding quotation about non-majors biology, written by West Virginia University (WVU) student Ry Rivard, appeared in the student newspaper. In contrast to Rivard's experience, according to the National Science Education Standards "science education is to . . . give students a foundation on which to base decisions they will face as citizens." (NRC 1996, 107) Feminist scholar Karen Barad (2001, 237) argues that many scientific literacy projects have failed because "the goal of scientific literacy may not be compelling to many of the 'scientifically illiterate' who have already grasped its irrelevance." Instead of "[s]tarting with an unchanged traditional curriculum and coating scientific facts with 'relevant examples' to make them go down easier" (237), Barad argues that attempts to help students see science as significant to their lives must fully engage with the nature of science as a social process. Barad identifies as inadequate the types of courses where a bit of philosophy or history is tacked onto the science content, where the science is watered down, or where social factors are overemphasized so that science seems to be only a product of culture. Overall, Barad wants to explore the "complex nature of the relationship between science and culture, rather than seeking causal explanations for one strictly in terms of the other." (228) Rivard echoes her critique—he calls for more than simple examples.

This project is an attempt to move toward the above goals in the non-majors biology course that Rivard critiqued. Although the nature of this large enrollment course limited the scope of our project, we hoped that our admittedly limited intervention would provide some practical strategies that instructors could try. Additionally, in this report we hope to build a dialogue between feminist literatures on science education and SENCER (Science Education for New Civic Engagements and Responsibilities) projects because we feel that each community has much to contribute toward enhancing student engagement and learning in large classes. Combining some of their approaches could be a fruitful strategy for future projects operating under constraints (lecture based formats, large enrollments, no graduate teaching assistant support, multiple sections with different instructors, etc.) similar to ours.

The SENCER project aims to answer Barad's and Rivard's challenges by "developing faculty expertise in teaching 'to' basic, canonical science and mathematics 'through' complex, capacious, often unsolved problems of civic consequence (SENCER)." Thus, "SENCER-ized" courses address the following goals: To encourage students to investigate the production of knowledge, participate in its construction and apply these skills to issues requiring civic engagement and responsibility. SENCER does not claim to generate these pedagogies but provides resources and a supportive community for faculty who wish to implement them. In this respect, SENCER shares the aims of many feminist science organizations (e.g., The National Women's Studies Association task force on science and technology), conferences (e.g., Inclusive Science in 2008 at the College of St. Catherine, St. Paul, MN), as well as various books and journal issues over the past two decades.

Feminist literature can provide helpful resources for SENCER projects. Feminist and other liberatory pedagogies link the natural sciences, the physical sciences and engineering with the social sciences, the arts and the humanities (Barscht 2004; Grasso et al. 2004; Mayberry et al. 2001; Riley 2004; Rosser 1997). Democratic pedagogies encourage collaboration and student knowledge construction (Cassidy and Cook-Sather 2003; Barton and Osborne 2000). Finally, these various pedagogies address the role of science in social justice projects (Bartsch 2004; Rosser 1997). Many share SENCER's goals to link content with pressing societal problems accessible to diverse groups of students, for instance by replacing military and sports examples (Whitten and Burciaga 2000) and including social justice issues such as environmental racism (Mayberry and Rees 1997; Schneiderman and Sharpe 2001). Girls may be attracted to science for societal benefit rather than strictly for the sake of discovery (Yanowitz 2004). Courses emphasizing this are attractive to female students (Jessup et al. 2005). Further, female engineering students responded more positively toward problem based learning than did male students (Du and Kolmos, 2009). However, some attempts to engage female students in majors classes have not succeeded in part because students think these new approaches take too much time, they don't like the collaborative nature, and they aren't sure if they have "learned the right thing." (Whitten and Burciaga 2000, 219-220)

Unfortunately, the structure of many introductory non-majors science classes is particularly challenging for feminist pedagogies, which are often based on personal engagement with students. Classes with hundreds of students typically emphasize lecture and a small number of high-stakes exams, rather than individual contact, collaborative learning, and discussion. These courses are currently fixtures at many large universities. However, to attain diversity goals and promote scientific understanding, it is critical to address large courses. For example, when students enrolled in non-majors biology at WVU were asked to write out their concerns about taking the course on the first day of class, roughly two times as many female as male students volunteered statements such as "I'm not a good science student", "I'm anxious about this class" and similar statements indicating negative experiences in previous science courses. In spite of these challenges, an analysis of a range of SENCER courses indicated that large courses were able to engage students with as many aspects of science practice as small courses (Utz and Duschl 2009). SENCER-ized courses help women, and non-science majors, gain confidence in their scientific abilities and interest in science (Weston et al. 2006). Thus, feminist science instructors could draw on resources from SENCER when faced with large classes.

Our project aims to integrate feminist and SENCERized pedagogies by exploring the interactions between science and the news media, and by doing so in a format that encourages students to develop their own connections to the material, to express themselves, and to develop connections with their peers. We hypothesized that connecting science information to issues of civic importance would encourage student confidence in their ability to apply scientific information to their lives and would also increase their interest in science. We expected women, and other groups traditionally underrepresented in science, to show especially significant gains. We hoped to significantly improve the student experience in a large, introductory course, while still working within the limitations and logistical challenges posed by curricular sequence, shared course policies, high student-to-instructor ratio, and classroom size. We specifically aimed to find ways to incorporate feminist strategies such as individual contact, collaborative learning, and discussion. To accomplish this goal we used low-stakes, and relatively quick to grade, written assignments that aimed to get students discussing science in their own words with their peers.

Methods

Biology 101 is an introductory, non-science majors biology course with 250 students per section which fulfills a general education requirement. The course covers the cell, genetics, evolution, and ecology in three hour-long lectures and one two-hour lab per week. It is taught in a large lecture hall with fixed, stadium-style seating; the instructors often rely on a wireless microphone to be heard. In the fall semesters, there are six sections taught by four different instructors who use a common text. In the spring two instructors teach two sections. These instructors carry out all aspects of the course without assistance from graduate teaching assistants or other paid helpers. Teaching styles vary: several instructors adhere almost exclusively to lecture, while others integrate varying degrees of interactive pedagogy. Efforts are made at uniformity between sections, while still allowing instructors some small latitude: all sections adhere to a similar sequence and timing of topics to match the required laboratory curriculum, similar grading policies are used, and assessment consists primarily of four multiple choice exams. The instructors have mutually agreed to allocate a small percentage of points (10–25 percent) for attendance, homework, or in-class participation to allow for personal preference and variation in teaching styles while keeping the grading system and student perceptions of "fairness" between course sections comparable. Students are primarily non-majors, although some science programs of study with general curricular goals do require Biology 101 because it is less intense than the majors course. The most common majors include general studies, education, sports management, criminology/investigation, psychology, and exercise physiology. Efforts underway to enhance student learning at the beginning of this project included linking of lab and lecture topics, online multiple choice homework questions based on reading assignments, and use of "clickers."

We used the "Biology in the News" approach in a single lecture section during spring 2007 (hereafter referred to as the "modified" section). We compared student attitudes in this modified section to students in two "traditional" sections (without the additional content described below) taught during fall semester 2006 (see Table 1). The same instructor taught all of these sections. In the modified "Biology in the News" section, we left the overall sequence of the material untouched in order to align with curriculum in the laboratory and other lecture sections. Most of the changes involved weekly written homework (graded by undergraduate TA's who received course credit) to maintain the level of student engagement in biology between exams, including six "Biology in the News" assignments. While such changes appear minor, these were the first assignments in this course to give students an opportunity to write about science in their own words and to include topics of personal interest, rather than merely to select pre-written multiple choice answers related to reading or lecture topics. We also incorporated weekly "guiding questions" related to reading assignments, which were written by the undergraduate TAs and randomly assessed through daily personal response "clicker" questions and infrequent, unannounced collection of student work. Both traditional and modified lecture sections utilized "clickers" and interactive

TABLE 1. Comparison of original Biology 101 (Fall 2006) course with Modified Biology 101 (Spring 2007) "Biology in the News" course

Timing	Original	Modified
Lecture components		
Lecture with slides	X*	X*
Participation credit, via "clicker" questions	X*	X*
Active participation credit, via coupons		X
Homework Components		
Electronic multiple choice quizzes	X*	X*
Guiding questions for reading		X
Written, news-focused homework		X
Multiple-choice Exams	X*	X*
Grade Breakdown (percentage), exams/homework/participation	85/5/10	75/15/10
Undergraduate Teaching Assistants		X

*The content of these components (lecture, electronic quizzes, and exams) were virtually identical between both courses.

demonstrations using models; the modified section also included a small amount of group work.

We expected students to be able to connect biology content to "real world" issues, identify differences between science writing and popular reporting of science, evaluate the content of a news article about a scientific discovery and discuss the flow of scientific information from the lab to the media. To achieve these learning outcomes, we invited Ralph Hanson, assistant dean of the WVU School of Journalism to guest lecture about the process of science being turned into news articles. He discussed the different understandings of key terms like objectivity and theory that are employed by journalists and scientists and how that affects the reporting of science. We also selected a press release about a study where taking aspirin decreased post-menopausal women's risk of pancreatic cancer. We asked the students to compare the press release with the original scientific article's abstract, and to evaluate the quality of the press release in terms of how effectively it conveyed the science. We then modified a search statement assignment "Translating English into Computerese" from Teaching Information Literacy Concepts: Activities and Frameworks from the Field, Active Learning Series No. 6 (Trudi E. Jacobson and Timothy H. Gatti, Contributing Editors). Students used their search terms find an article about a scientific topic of their own choosing in Lexis-Nexis, a database that searches newspapers, magazines, and some journals. The previous assignments encouraged development of basic skills that the later more collaborative, personalized assignments required. To encourage reflection, we developed a discussion board that required students to post a news article for comment from their classmates regarding connections to class, the quality of the report of the science, and the social and civic significance that the reporter gave the work. One-half of the group posted an article and the other half responded with a critique. The roles were reversed on the next discussion board.

We used both qualitative and quantitative assessments. Our quantitative measure was the SENCER Student Assessment of Learning Gains (SALG; www.salgsite.org). We compared SALG survey results between the 2006 traditional sections and the 2007 modified section. Students used a confidential identification number so all responses were anonymous. Multiple questions were grouped into general categories of items indicating confidence and interest in science. Students identified their level of interest, confidence or agreement/disagreement using Likert scales. This version of SALG had pre- and post- versions allowing instructors to compare student responses at the beginning and end of the course. Pre-course questions had the following format: Presently, I am confident I can think critically about scientific findings I read about in the media. Post-course questions were modified in the following way: After finishing this class, I am confident I can think critically about scientific findings I read about in the media. We added the following questions directly related to content covered in BIO 101:

1. I am confident that I could get information about a genetic issue that affected me or my family.
2. I am confident that I could understand an article about a new type of biotechnology.
3. I am confident that I could understand the scientific side of a debate about evolution in my own school district.
4. I am confident that I could weigh the scientific evidence about environmental issues and decide where I stand.

Qualitative assessment information was collected through free-response SENCER SALG questions. The SALG also collected demographic data, as well as information about which activities helped students learn. The SALG pre-survey was administered within the first month of class, whereas the students completed the post-survey during the last two weeks of class. Students were offered a small amount of extra credit (two percent of course grade). According to the WVU IRB procedures at the time of this research, the study protocol was submitted to the associate dean for research of WVU's Eberly College of Arts and Science and was declared "exempt."

The three sections enrolled approximately 750 students (250 per section). A total of 407 students (174 males, 229 females, and four of unknown sex) completed both the pre- and post- surveys. Among those students, twelve were African American (eight female), eight were Asian or Pacific Islander (seven female), three were Hispanic (two female), thirteen did not record their ethnicity (six female, three sex not recorded) and 371 were Caucasian (206 female, one sex not recorded). We also collected information on the students' ages, year in school and current GPA, as well as their reason for taking the course. Using a Kruskal-Wallis test, we found no significant differences in ethnicity or sex among the three sections; however, students in the modified section (spring 2007) were older, further along in their studies and had higher GPA's than in the traditional sections (fall 2006). We controlled for these differences in the statistical analyses by including these variables as covariates. Additionally, there were differences among students in their motivation for taking the course between the modified and one of the traditional sections: students in the modified section were less likely to be taking the course because it was a prerequisite for another course. We expect this was related to the fact that these students were further along and were probably fulfilling general education requirements, thus we did not control separately for this. Motivation was not significantly different among the other sections. We pooled the data from the two traditional sections for comparison with the modified section using repeated measures multiple analysis of covariance (MANCOVA). For the purposes of analysis, we used the mean Likert scores for the confidence and interest groups of questions on the SALG, except for the course specific questions that we added, which were analyzed individually.

Results

Student confidence and interest increased in both the modified and traditional sections. However, only confidence gains were significantly greater in the modified In the News course than the traditional course (Figure 1, $F = 22.621$, $df = 1,387$, $p < 0.001$). No significant differences between the modified and traditional course were observed for gains in interest. There were no significant effects of sex or ethnicity on either confidence or interest gains. Gains were also significantly greater in the modified course for questions in which students rated their ability to apply specific topics from the course to their daily lives in the areas of getting information about genetic issues affecting their families (Figure 2, $F = 6.774$, $df = 1, 364$, $p = .008$), understanding the scientific side of the debate over evolution (Figure 2, $F = 8.507$, $df = 1, 364$, $p = .004$), weighing scientific evidence about environmental issues (Figure 2, $F = 5.536$, $df = 1, 364$, $p = 0.019$), but not understanding an article about a new type of biotechnology (Figure 2, $F = .036$, $df = 1, 364$, $p = .851$). Since the course did not end up covering information about biotechnology, this result is to be expected. There were no effects of sex or ethnicity on gains in these areas; students in all groups showed the same degree of gains.

When students were asked how much thirty-four different items helped them learn, "links to recent news" ranked twelfth

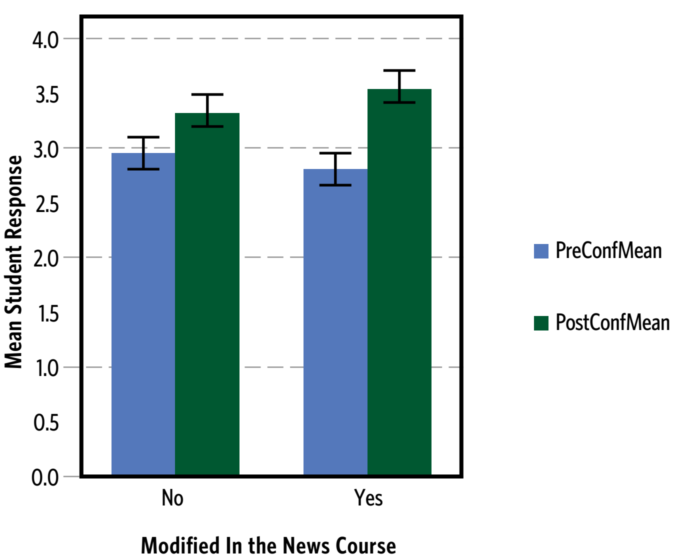


FIGURE 1. Increased Confidence. Overall, students in the modified section had significantly higher gains in "confidence" itmes but not "interest" items on the SENCER SALG than students in the traditional sections. Repeated Measures MANCOVA.

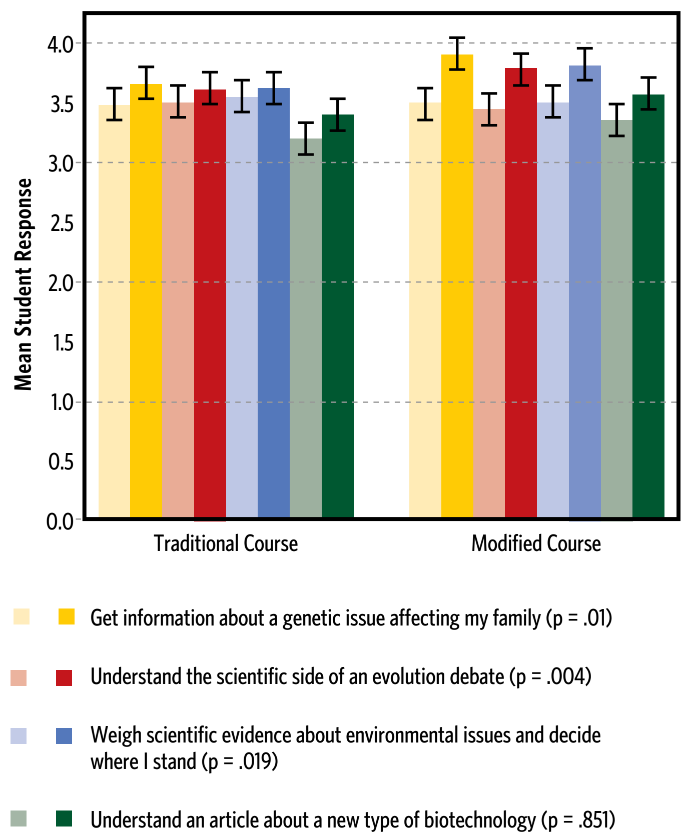


FIGURE 2. Applying Biology to Everyday Life. Students reported significantly higher gains in confidence to do tasks related to curriculum topics in the modified course in all areas except biotech. Repeated Measures MANCOVA.

highest, "Biology in the News" homework ranked twenty-fourth, and "Biology in the News" discussion boards ranked thirty-second (see Figure 3 for complete list). When students listed the assignments and activities that most helped them learn in the SALG free-response section, the following were mentioned most frequently:

1. "Clicker" questions;
2. Lecture;
3. Demonstrations or models;
4. Online quizzes;
5. Lecture examples and slides;
6. "Biology in the News" homework;
7. Lecture notes;
8. Lab activities;
9. The textbook; and
10. Guiding questions.

Student comments indicated that among the "Biology in the News" assignments, they preferred the discussion boards for their interactive qualities and the chance to relate a variety of topics to class materials (Table 2). However, approximately fifteen percent of survey comments suggested eliminating or changing "Biology in the News" assignments, with one of the most common suggestions being to better link the assignments to lecture content (Table 2).

Discussion

Our study illustrates that even limited feminist interventions can accomplish positive changes in the student experience. As we predicted, connecting science information to issues of civic importance enhanced student confidence in their ability to apply scientific information to issues relevant to their lives—even with just minor changes to course format and content. However, although we saw gains in student interest in both the traditional and modified sections, we did not see a greater impact on student interest in the modified section. Non-science majors, such as our students, may gain confidence in their abilities but not interest in taking further science courses because they are already committed to a non-science path that precludes more science coursework (Bower et al. 2007). The limited changes we made to lecture and the lack of its integration with the "Biology in the News" theme

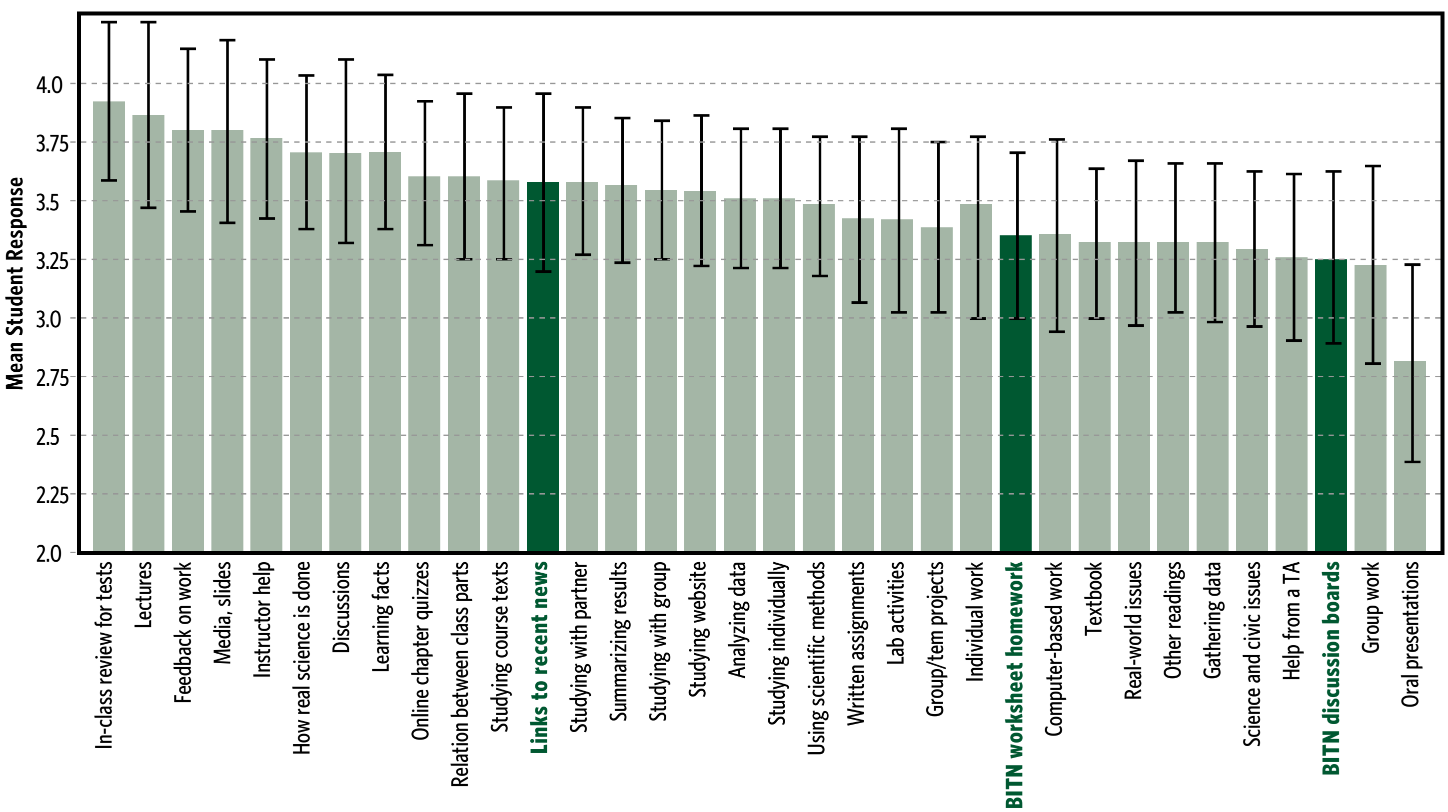


FIGURE 3. Student Rankings. Which course activities and assignments most helped them learn.

may have further limited the impact on student interest, since lecture was still the most visible and time-consuming component of the course. "Topic fatigue" regarding "Biology in the News" could certainly be a factor; students who are asked to immerse themselves in a topic can grow tired of it by the final assessment period (Pike and Hanson 2007), thus mitigating the impact of being able to explore topics of personal interest. However, we contend that an increase in student confidence in one's ability to digest and apply science to one's personal life, such as our results indicate, is a worthy achievement, meriting further exploration.

We expected women, and other groups traditionally underrepresented in science, to show especially significant gains. However, although we saw overall gains for all students, we did not see greater impacts on these specific groups. Due to the small number of minority students in the study population, it is difficult to draw meaningful conclusions. However, we did find overall positive impacts on both male and female students, and for both whites and people of color, as a result of our intervention. Other similar approaches have also positively impacted the confidence and interest of both male and female students (McEneaney and Radeloff 2000). However, the mechanisms behind these gains are an important area for future research. Overall, we saw gains by both males and females, with no differences in magnitude between the sexes. However, it could be possible that the reasons for the gains differ between the sexes. For example, although both male and female students engage more positively with science when the content is linked to issues relevant to the student, the specific interest areas frequently differ between the sexes (Teppo and Rannikmäe, 2003; Gedrovics, 2006). Thus, the mechanisms by which we achieved an impact might also differ between the sexes. To address this question, our future research will examine more closely the qualitative responses and selected news topics of male and female students.

This study's results also highlight an important issue to address in implementing meaningful curricular change: integrating societal relevance into high-stakes as well as low-stakes assessments. Some of our students who identified the "Biology in the News" assignments as fun or educational did not see them as useful to their learning because of a perceived gap between these assignments and the lecture content and tested material. We expect this factor to underlie the relatively low ranking of the discussion boards among the items that students identified as helpful to their learning. Finding meaningful ways to gain student buy-in for innovative pedagogies in large, non-majors classes is a key step toward the enhancement of student learning. An inherently conservative student approach to learning, particularly in courses outside their major, requires that instructors make sure that integrated content is seen by students as relevant to the course assessments. This is especially important in large science classes which require

TABLE 2. Samples of Student Comments (Free Response, SALG Post Assessment)

Positive Comments	Negative Comments
I think I liked [the Biology in the News discussion boards] best because they relate more to real life, and I don't think they felt that much like homework.	I simply did not understand the significance behind it all. I understand the intention to relate textbook science to the real world, but I did not feel that those assignments were of any real value.
[Discussion boards] allowed me to do research about topics that we discussed in class and get feedback from my fellow classmates. I think that it is a good interaction between students and it helps make a big class not so anonymous. It also helped me become more familiar with using scientific websites that I could possibly use in the future on a paper.	Even though I learned from them, I still don't think that they helped me learn definite material for the tests.
I enjoyed searching my topic because it gave some freedom and it helped me learn a little more about the topic I was interested and didn't force one on me.	I felt like we did the assignments just for a grade and then we really did not talk about it in class.
Most courses you learn things and you think, . . . "How is this related to my life?" These two [discussion boards] proved that biology is a part of our lives and is constantly in the news.	At first I didn't really care for them, but as the assignments started holding more relevance to the course matter I realized where she was going with all of it.

multiple choice testing and where students may have been conditioned to succeed by memorizing rather than engaging with material in assignments that are reflective, research and writing intensive. Inclusion of societally relevant material on exams, as well as more obvious integration of the biological content into personally engaging, socially relevant homework, may improve student perceptions of these activities in the future. Future research should examine the impacts of more explicit linkages among material in lecture, and on high and low stakes assessments.

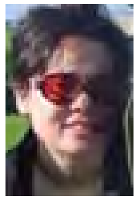
An additional reason behind this student "resistance" could also be that our intervention did not go far enough in answering Barad's and Rivard's calls to explore the "embeddedness" of science within a societal context. Our conservative efforts thus far to maintain cohesion between course sections and curricula limited the degree of our curricular changes. Furthermore, the lack of a greater impact on students' interest in science than in the traditional course may be explained because many students do not find the news to be particularly relevant to their lives or to be especially interesting or engaging. Increasing student awareness of and engagement with current events, however, still seems a worthy goal. In other news related projects, such student engagement has been critical for success. McCullough (2006) asked students to summarize an article and reflect on why they picked it. She found that articles linked to students' majors or non-scholastic interactions were more likely to be selected. The "Chemistry in the News" project at the University of Missouri not only links chemistry with current societal issues; but also employs peer review of portfolios, collaborative group work, and online tools to build a sense of community in large chemistry courses (Carson et al. 2006; Glaser and Carson 2005). The assessment of that project found that those students who came into the course expecting that connecting course material to societal issues would make it more interesting and easier to understand had more positive attitudes toward the subject and the assignments by the end of the course. We agree with their advice that instructors must discuss with students how the societal connections and projects will facilitate learning at the beginning of the course.

Our results indicate that, in addition to the logistical problems with pedagogy reform in large classes, getting students on board can be challenging. Encouraging students to self-identify the relevance of science to their lives is an integral part of both feminist and SENCERized goals. In this area, we were successful as a number of the student comments indicated that they either valued freedom to select their own topics or that they wanted more freedom in how they identified links to course content material. Thus, in future efforts we plan to build on this response to enhance student engagement. Given that students appeared to respond positively to the discussion boards due to the possibility for interaction with their peers, we are exploring means of using this method with other topics that students may find more relevant, such as medical issues. Fink (2009) used cancer as an issue with which to engage introductory biology students by integrating material on treatment with personal narratives of those afflicted by cancer. Feminist approaches provide other useful strategies. Introducing feminist analyses and women's studies content helps students see how to balance work and life (Whitten and Burciaga 2000; Rosser 1997) and deal with sexual harassment and other forms of discrimination (Weasel et al. 2000). Other successful courses highlight the overlooked contributions of members of underrepresented groups, such as women in ecology (Damschen et al. 2005) or non-Western approaches to thermodynamics (Riley 2003). The feminist approach defines diversity broadly and can benefit nearly all students; for example, engineering education programs train people to work in diverse teams and also to develop technologies for diverse users (Ihsen and Gebauer 2009). These types of topics could be used to explore the personal issues faced by scientists in their careers or applications of science and technology to a variety of societal issues. Our future efforts will focus on carefully blending topics and resources to foster student personal engagement with course content. We expect that explaining the reason for and benefits of added societally relevant material, as well as its more complete integration into the course, will be reflected in further gains in student interest, confidence, and engagement with both biology and current events.

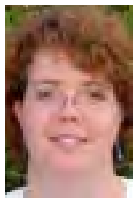
Acknowledgments

We would very much like to thank Dr. Melissa Latimer and three anonymous reviewers for comments, which greatly improved this manuscript. This work originated at the 2006 SENCER Summer Institute, and was further supported by a 2007 SENCER/NSF Post-Institute Implementation Award.

About the Authors



J. Kasi Jackson is an assistant professor in the Center for Women's Studies at West Virginia University. In addition to science education research focusing on diversity, she also studies the representation of science in popular film and science fiction literature. She completed her Ph.D. in biology at the University of Kentucky. She may be contacted at kasi.jackson@mail.wvu.edu.



Jane Caldwell is currently an Adjunct Instructor at Washington and Jefferson College, in Washington, Pennsylvania. She is also delighted to be mother to a three month old baby girl, Erin Caldwell Klitz. For the previous six years, she was a clinical assistant professor at West Virginia University, where she coordinated the lab and lecture program for non-majors, and occasionally taught a course on protein structure and function.

References

Barad, K. 2001. "Scientific Literacy → Agential Literacy = (Learning + Doing) Science Responsibly." In *Feminist Science Studies: A New Generation*, M. Mayberry, B. Subramaniam, and L. Weasel, eds., 226–246. New York, NY: Routledge.

Bower, A., J. Ashley, G. Buchanan, J. Dispensa, J. Pierce, and F. Ross. 2007. "Fostering Science Literacy: Non-science Majors Discover the Science behind National Public Health Issues." *Science Education and Civic Engagement: An International Journal* Winter 2007: 24–39. seceij.net/files/seceij/science_education_civic_engage.pdf (accessed December 30, 2010).

Barton, A.C. and M.D. Osborne. 2000. "Building Inclusive Science in Classrooms Through Oral Histories." *Women's Studies Quarterly* 28 (1/2): 236–250.

Bartsch, I. 2004. "Re-Visioning Science Education." *Journal of International Women's Studies* 5 (4): 44–56.

Carson, K.M., B. Hodgen, and R.E. Glaser. 2006. "Teaching Dissent and Persuasion." *Educational Research and Reviews* 1(4): 115–120.

Cassidy, K.W. and A. Cook-Sather. 2003. "Putting the 'Social' Back in 'Socially Constructed': Revising the Teaching of Psychology as and in Collaboration." *Journal of Women and Minorities in Science and Engineering* 9: 35–51.

Damschen, E.I., K.M. Rosenfeld, M. Wyer, D. Murphy-Medley, T.R. Wentworth, and N.M. Haddad. 2005. "Visibility Matters: Increasing Knowledge of Women's Contributions to Ecology." *Frontiers in Ecology and the Environment* 3 (4): 212–219.

Du, X. and Kolmos, A. 2009. "Increasing the Diversity of Engineering Education—A Gender Analysis in a PBL Context." *European Journal of Engineering Education* 34(5): 425–437.

Fink, M. 2009. "Preparing Future Teachers Using a SENCER Approach to Positively Affect Dispositions Toward Science." *Science Education and Civic Engagement: An International Journal* Winter 2009. seceij.net/seceij/fall09/preparing_futur.html (accessed December 30, 2010).

Gedrovics, J. 2006. "Regional and Group Differences in the Framework of International Comparative Project ROSE in Latvia." *Journal of Baltic Science Education* 1(9): 74–85.

Glaser, R.E. and K.M. Carson. 2005. "Chemistry Is in the News: Taxonomy of Authentic News Media-based Learning Activities." *International Journal of Science Education* 27 (9): 1083–1098.

Grasso, D., K.M. Callahan, and S. Doucett. 2004. "Defining Engineering Thought." *International Journal of Engineering Education* 20(3): 412–415; reviewed in L.M. Frehill, L.N. Ketcham, and C. Jeser-Cannavale, 2005, "Women in Engineering: A Review of the 2004 Literature," *SWE Magazine* 51 (3): 22–46.

Ihsen, S. and S. Gebauer. 2009. "Diversity Issues in the Engineering Curriculum." *European Journal of Engineering Education* 34(5): 419–424.

Jessup, E., T. Sumner, and L. Barker. 2005. "Report from the Trenches: Implementing Curriculum to Promote the Participation of Women in Computer Science." *Journal of Women and Minorities in Science and Engineering* 11: 273–294.

Heidi J., and S. Barker. 2009. "How High-School Students Find and Evaluate Scientific Information: A Basis for Information Literacy Skills Development." *Library and Information Science Research* 31: 12–17.

Mayberry, M., B. Subramaniam, and L. Weasel, eds. 2001. *Feminist Science Studies: A New Generation*. New York: Routledge.

Maralee M., and M.N. Rees. 1997. "Feminist Pedagogy, Interdisciplinary Praxis, and Science Education," *National Women's Studies Association Journal* 9(1): 57–75.

McCullough, L. 2006. "Science News and the Science Classroom." *Journal of College Science Teaching* 36(3): 30–33.

McEneaney, E.H. and C.L. Radeloff. 2000. "Geoscience in Social Context: An Assessment of Course Impact on Attitudes of Female Undergraduates." *Journal of Women and Minorities in Science and Engineering* 6 (2): 131–153.

National Research Council (NRC) and National Committee on Science Education Standards and Assessment. *National Science Education Standards* Washington, D.C.: National Academies Press, 1996. www.nap.edu/books/0309053269/html/index.html (accessed December 30, 2007).

Pike, L. and L. Hanson. 2007. " Environmental Science and Communication: An Interdisciplinary Venue for Teaching" *Science Education and Civic Engagement: An International Journal* Fall 2007: 20–36. seceij.net (accessed April 12, 2010).

Riley, D. 2003. "Employing Liberative Pedagogies in Engineering Education," *Journal of Women and Minorities in Science and Engineering* 9(2): 10.1615/JWomenMinorScienEng.v9.i2 (accessed September 4, 2007).

Rivard, R. 2006. "Technology isn't the Key to Quality Education." *The Daily Athenaeum*, Oct. 19, 2006.

Rosser, S.V. 1997. *Reengineering Female Friendly Science*. New York: Teachers College Press.

Schneiderman, J.S. and V.A. Sharpe. 2001. "An NSF Sponsored Curriculum that Moves Students Toward a Feminist Earth Science." *Women's Studies Quarterly* 1/2: 234–243.

Science Education for New Civic Engagements and Responsibilites (SENCER). www.sencer.net (accessed September 1, 2007).

Teppo, M., and Rannikmäe, M. 2003. "Increasing the Relevance of Science Education–Student Preferences for Different Types of Teaching Scenarios." *Journal of Baltic Science Education* 2(4): 49–61.

Utz, A.H. and R.A. Duschl. 2009. "SENCERizing Pre-service K–8 Teacher Education: The Role of Scientific Practices." *Science Education and Civic Engagement: An International Journal* Fall: seceij.net/seceij/fall09/sencerizing_pre.html (accessed December 30, 2010).

Weasel, L.H., M. Honrado, and D.P. Bautista. 2000. "The Forgotten Few: Developing Curricula on Women in the Physical Sciences and Engineering." *Women's Studies Quarterly* 28 (1/2): 251–263.

Weston, T., E. Seymour, and H. Thiry, "Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project," www.sencer.net/Assessment/pdfs/Assessment/FINAL_REPORT_SENCER_12_21_06.pdf (accessed December 30, 2010).

Whitten, B.L. and J.R. Burciaga. 2000. "Feminist and Multicultural Pedagogy in Physics: A Status Report," *Women's Studies Quarterly* 28 (1/2): 213–235.

Yanowitz, K.L. 2004. "Do Scientists Help People? Beliefs About Scientists and the Influence of Prosocial Contexts on Girls' Attitude Toward Physics." *Journal of Women and Minorities in Science and Engineering* 10: 393–399.

REVIEW ARTICLE

A Review of the Literature on Increasing the Representation of Women Undergraduates in STEM Disciplines through Civic Engagement Pedagogies

David B. Knight
Higher Education Program
Pennsylvania State University

Ellen F. Mappen
National Center for Science & Civic Engagement

Stephanie L. Knight
Educational Psychology Program
Pennsylvania State University

Introduction

Despite recognition of the importance of student diversity in enhancing undergraduate STEM education (e.g., Augustine 2005), gender gaps persist in quantitative fields such as physical sciences and engineering (AAUW 1998; Brickhouse 2001; Brotman and Moore, 2008; Campbell et al. 2002; Fadigan and Hammrich 2004; Gilbert and Calvert 2003; Herzig 2004; National Science Board, 2010; Scantlebury and Baker 2007). When individuals of diverse perspectives come together in a group, innovative initiatives tend to be born because varying interests and experiences lead to an amalgam of ideas (e.g., Barber 1995; Frehill et al. 2006; National Research Council 1991; Valian 2005). Therefore, it is important to better understand the contributing factors to this gender imbalance and explore potential avenues that could work toward increasing the representation of women in the field.

This review highlights research that attempts to explain gender differences in recruitment, performance, and achievement in the STEM fields and discusses how differing pedagogies can affect participation within programs in the United States. An interesting additional analysis could compare U.S. STEM curriculum and pedagogy as it relates to successfully recruiting and retaining women to approaches taken in other countries. The general focus is on gender preferences in science courses and variations in confidence levels between males and females with respect to science performance at the classroom level. The review includes examination of scholarship that summarizes effective pedagogical processes and environments in secondary and postsecondary STEM education for females. Finally, this review suggests a potential path towards the diversification of STEM disciplines by describing programs that have successfully spurred an interest among women through the implementation of pedagogical techniques characterized by civic engagement.

Current State of the STEM Gender Gap

There has been a strong push by the federal government to increase the STEM workforce since the Russians launched Sputnik in 1957. The United States has maintained the desire to remain at the forefront of the world in discovery and innovation (Geiger 2004). In 1983, the National Commission on Excellence in Education published *A Nation at Risk: The Imperative for Educational Reform* in which public school teaching and learning was assessed. The report indicated that the generation of students moving through the public school systems were both scientifically and technologically illiterate (NCEE 1983). Efforts directed toward improving science education have been made since this scathing assessment. For example, the Improving America's Schools Act of 1994 made funds available to provide equipment and materials for hands-on science and math instruction in K–12 settings. Funding also increased in 2006 and 2007 in three separate education-based policy programs that provided additional resources for technology education and improved STEM teacher preparedness (American Competitiveness Initiative 2006; America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act 2007; Carl D. Perkins Career and Technical Education Act 2006). More recently, President Obama indicated plans to expand the Educate to Innovate campaign in K–12 science and math education. As such, there has been an emphasis from the federal government on increasing the exposure to quality STEM education during a student's secondary school experiences through various funding and mandating strategies. Though these legislative acts target all students, the National Science Foundation has supported efforts to address gender differences in STEM fields since 1993.

Results suggest positive gains have been realized, as postsecondary enrollment in the STEM fields for all undergraduates has steadily escalated over the past fifteen years. In addition, the number of bachelor's degrees in these disciplines reached a new peak in 2007 (NSB 2010). There has also been a profound increase in the proportion of women entering STEM disciplines. This proportion has increased from 1993–2007—females have accounted for 58 percent of all bachelor's degrees since 2000 and have earned approximately half of all STEM degrees over the same time period. However, gender disparities in bachelor's degree attainment continue to exist in certain STEM disciplines, specifically in physical sciences and engineering. For example, women earned at least half of all bachelor's degrees in psychology (77 percent), biological sciences (60 percent), social sciences (54 percent), agricultural sciences (50 percent), and chemistry (50 percent). In contrast, men earned 81 percent of engineering degrees, 81 percent of computer sciences degrees, and 79 percent of physics degrees in 2007. Similar gender preferences across STEM disciplines are evident for graduate degrees, as women earned only 31 percent of physical science, 26 percent of mathematics/computer sciences, and 23 percent of engineering doctorates while accounting for over half of social/behavioral sciences, medical/life sciences, and non-STEM doctorates (National Science Board 2010). Understanding the causes of this disparity in certain disciplines is important so that viable solutions can be developed to achieve a more balanced gender composition in all STEM fields. As subsequent sections in this review suggest, implementing innovative pedagogical strategies at the classroom level that have a firm grounding in research on gender learning theory may partly address the issue.

K–12 Achievement in STEM

Comparisons in STEM achievement between males and females could possibly help inform decisions on how to decrease the gender gap. If females have markedly lower achievements than males in STEM fields upon high school graduation, for example, remediation programs could be offered at the college level to promote recruitment and retention in these disciplines. In a study of male and female students in the eighth grade, Catsombis (1995) compared gender differences in both science achievements and attitudes. She found that on average females achieved equivalently to males, and some showed a greater likelihood of enrolling in higher level classes than their male counterparts. However, females also had less positive attitudes about science and less frequently aspired to a career in science.

Similarly, Campbell et al. (2002) compared STEM achievements and attitudes by gender throughout both the K–12 sequence and within postsecondary settings. Males and females scored similarly on tests in the fourth grade, but males tended to develop physical science and technology-related interests, whereas females tended to track toward life sciences at this early age. Eighth graders showed little differences in science and math test scores by gender, but females were more likely to begin algebra coursework by this stage of their educations despite having lower confidence than males in their own math abilities. In addition, twice as many males as females were interested in quantitative or science disciplines by this grade level. High school seniors also showed no differences across gender in achievement, as both males and females were as likely to take advanced coursework. Females were less likely than males to express a desire to major in computer/

information science, science, engineering, or math, and this was later realized through their selection of college programs. Considering racial demographics, the gap in achievement between white students and minority students tended to widen at each successive grade level observation point, but interest in science and math subjects did not vary between these demographic groups. Therefore, the researchers found that, in aggregate, women graduate from high school with comparable knowledge and skills to men in the STEM fields. Furthermore, once women declare a major in one of these fields, they persist at a rate proportional to men. Minority students, on the other hand, are more likely to transfer out of STEM majors prior to degree attainment because, on average, they enter college without the academic preparedness required of these disciplines. As such, institutions of higher education face varying sets of issues in enrolling students into STEM fields dependent upon the student demographic characteristics. For all women, recruitment is a major barrier to enrollment, but institutions also struggle with retention for minority women. Therefore, researchers should take into account the interaction of gender and race in studying students enrolling in STEM fields (Campbell and Storo 1994), and practitioners should recognize the multifaceted nature of the problem.

Differences Across Academic Disciplines

Because research shows no gender differences in STEM achievement, it stands to reason that there are other discipline-specific characteristics that lead to gender imbalances. Work by Brint et al. (2008) identified different cultures of student engagement across broad disciplines. Using the National Survey of Student Engagement (NSEE), they identified five dimensions of effective academic engagement, including active or collaborative learning, student-faculty contact, level of academic challenge, enriching educational experiences, and supportive campus environment. A factor analysis of the engagement items yielded two different cultures that separated according to academic discipline:

1. A humanities/social sciences culture characterized by high student/faculty interaction, discussion and questioning by students in classes, the connection of ideas across courses, and students who go above and beyond the required workload.
2. A science/engineering culture dominated by high quantitative and computer skills, high levels of collaboration with peers, a focus on problem solving, and a pervasive interest in obtaining high-paying and prestigious jobs.

This finding of multiple engagement cultures across fields is not very surprising since there is a variation in the roots of content and views of knowledge across disciplines. The authors clearly assert that students are recruited into a field and undergo a socialization in which they discover and adopt the attributes that are recognized within the field. They cite the field's paradigmatic development as an indicator of the culture, with low paradigmatic fields (humanities and social sciences) encouraging flexibility and discussion, and high paradigmatic fields (science and engineering) promoting more structure. The science/engineering culture of engagement is characterized by specific skill sets in which students work together to solve problems incrementally because, historically, there has been little room for extra discussion on how to approach problems. On the other hand, the humanities/social sciences engagement culture of increased discussion and active class participation is expected, as students and teachers struggle over several possibilities rather than the "one correct answer." Since faculty members at universities have been trained according to certain paradigms, they tend to propagate the corresponding culture of engagement with students through their own teaching (Brint et al., 2008). Similar work by Sheila Tobias (1990) identifies how different cultures of engagement of the disciplines may either attract or repel students from enrolling in a major.

Nelson Laird et al. (2008) compared deep approaches to learning (including higher-order, integrative, and reflective learning) across combinations of Biglan's disciplinary categories, a classification system that describes disciplines across the following dimensions: applied–theoretical, hard–soft, life–non-life. Similarly, they found that the extent to which deep learning techniques are put into practice varies by discipline, with soft, pure, and life fields using deep approaches more frequently than hard, applied, non-life fields. This latter group represents disciplines in which women are currently underrepresented. Like Brint et al. (2008), they attributed differences in the use of engagement techniques to the degree of consensus, or paradigm development, within various fields. Since different disciplines have unique cultures of engagement, females and males may select a field of study that is a better match for their personal engagement style.

Even within STEM fields, there are differences in the representation of women across disciplines. In engineering, for example, studies show differences in female representation among disciplines (e.g., mechanical, industrial). Research on nine southeastern universities showed that industrial engineering, chemical engineering, and civil engineering have a higher percentage of women enrolled than the other engineering disciplines (Borrego et al. 2005). Similarly, Jenkins and Keim (2005) found that female students in one university preferred biomedical engineering, civil engineering, and chemical engineering and were not as well represented in mechanical and computer engineering. However, these studies stop short of explaining *why* there are differences. Following the logic of Brint et al. (2004), perhaps certain disciplines within the STEM fields have cultures of engagement that are more attractive to females as they search for a home discipline.

There is a wide body of literature on how students select a major field of study. The decision is an important indicator of career choice, earnings, and professional satisfaction. Many factors have been shown to contribute to this choice, including gender (e.g., Jacobs 1986, 1995), race (e.g., Thomas 1985), ethnicity (e.g., Simpson 2001), and labor market returns (e.g., Cebula and Lopes 1982; Davies and Guppy 1997). While there is an extensive literature on the influences that a student's background has on access to and success in higher education, there is a void in how it influences his or her academic plan (Goyette and Mullen 2006). Considering gender issues, the choice of a major is a logical starting point for analyzing differences between males and females in career choice and earnings (Barres 2006; Daymont and Andrisoni 1984).

Zafar's (2009) academic major choice model was applied to students at the Weinberg College of Arts and Sciences at Northwestern University. Students select a major according to expected outcomes during college, anticipated outcomes after college, and individual characteristics, including gender. In efforts to test their major choice model, they surveyed students to gain an understanding of their thought processes during this important academic decision. Gender comparisons on self confidence, self efficacy, and ability showed no differences between males and females in factoring into the declaration of a major in science or engineering. Rather, a difference across genders in the likelihood of enjoying the coursework of science or engineering was the most important determining factor. Therefore, using the findings from this major choice study as supporting evidence, incorporating pedagogical techniques in science and engineering that have successfully attracted females to other disciplinary cultures may be a successful tactic for recruitment.

Another determining factor in decisions about major fields of study is related to sexual stereotyping (e.g., Metz and Samuelsen 2000). Differences exist across disciplines in the degree to which sexual stereotyping occurs. Society has a pervasive view that science and engineering professions are "male-dominated" thereby causing negative attitudes toward these disciplines among women; this phenomenon is an example of sexual stereotyping. Relative to men, women tend to have less overall interest and perceive fewer educational and career benefits by pursuing these areas (NRC 2006). Despite an overall weak understanding of what engineers actually do by the general public (e.g., Cunningham et al. 2005; Cunningham and Knight 2004; NAE 2008), the sexual stereotyping of the "white male" engineering profession still begins at a young age and is carried throughout life, making it discouraging for women to enroll in programs once they reach college (Metz and Samuelsen 2000). Perhaps the field has sustained this stigma within the general public because it has always been dominated by white males, but the literature has not resolved the cause of the perception. This stereotype threat has been shown to negatively influence performance, as women must cope with feelings of isolation within STEM fields. In a study of females assigned to either a stereotype threat condition or no condition while taking a math test, women under the threat condition reported higher negative feelings with respect to math during the exam. The control group also performed better overall than the group under threatening conditions (Cadinu et al. 2005). In similar research, Kiefer and Sekaquaptewa (2007) observed students in a college-level calculus course under various sexual stereotype conditions. Women under the treatment performed worse on the course's first exam and had a reduced desire to pursue a math-related career relative to women who experienced low stereotyping. Claude Steele's (2003) work also showed that sexual stereotyping explained why women who were equally prepared for challenging math courses underperformed relative to classmates of the same intellectual level. Finally, research by Krendl et al. (2008) focused on how cognitive structures vary under different conditions of sexual stereotype threat. Using magnetic resonance imaging to determine which neural structures explained the underperformance on math tasks in certain females, they found that certain neural networks are activated during mathematical learning. If a female is in a threat condition, rather than activating this neural network, she instead activates a neural network that controls social and emotional processing. Thus, women who are in a threat situation may not perform as well because the threat causes a preoccupation of the cognitive process.

In summary, clear differences exist between disciplines in the ways that they present themselves to students and thus their attractiveness to women. The different academic cultures of science and engineering versus humanities and social sciences may indicate that women are more attracted to a certain type of engagement in the classroom. Even within STEM, women tend to gravitate toward the soft, pure, life fields (NSB 2010). Academic major choice theory with respect to STEM suggests that women may be underrepresented because they are simply uninspired by potential coursework, suggesting that shifts in pedagogical techniques could potentially influence recruitment. Finally, differences in sexual stereotyping between disciplines also may steer females to enroll in certain fields and avoid others.

STEM-Specific Difficulties in Recruitment and Current Recruitment Techniques

Many studies, especially at the K–12 level, have attempted to determine why it is difficult to recruit women into STEM fields. Reviews of the literature group explanations into broad categories, including precursors, interests, confidence, peer interactions, teacher interactions, and performance (e.g., Bachman et al. 2009). Parents have a large influence on their sons and daughters and act to maintain gender-based norms in society (Bhanot and Javanovic 2005; Buchmann and Dalton 2002). According to these norms, the STEM fields as a potential career destination for their students has a more masculine than feminine connotation (Nosek et al. 2002; Tiedemann 2000). Another potential reason for gender differences is related to variations in subject interests. On average, males prefer structured, goal-oriented subjects (Abu El-Haj 2003), and STEM courses have traditionally been (Donald, 2002) and largely still are (Lattuca and Stark, 2009) arranged in a sequence-driven, hierarchical manner based on continuously building information from a foundation of concepts, though some recent, select efforts have experimented with more innovative curricula (e.g., Beichner et al. 2007).

There is some evidence that men and women in STEM fields have differing levels of self-confidence (e.g., Schunk and Pajares 2002). Despite entering college with achievement and confidence levels similar to men, women in STEM fields tend to lose that confidence upon matriculation, potentially because of feelings of isolation when they are underrepresented in certain disciplines (Seymour 1995; Whitt et al. 2003). Interactions with male peers who believe women enrolled in STEM fields can either be smart or attractive, but not both, can also be harmful to a their confidence and retention within the field (Seymour 1995). If a female is perceived to be smarter than her male counterparts, she will often be omitted from study groups and lose access to an encouraging peer network (Stake and Nickens 2005).

Considerable efforts already have been made to combat some of these barriers and recruit female students to STEM (e.g., Plumb and Reis 2007).These include professional development programs for K–12 teachers, hosting summer camps targeting underrepresented groups, and developing outreach instructional materials for secondary school settings. Individual institutions of higher education have made substantial efforts to address the chilly climate amongst peers through undergraduate mentoring programs intended for women (e.g., Campbell and Skoog 2004) and STEM learning communities for women (e.g., Kahveci 2006). For example, Kahveci (2006) studied the recruitment effectiveness of a living-learning community for women in science, math, and engineering. In this community, students lived together, formed mandatory study groups, participated in organized activities, and held colloquium, lectures, advising, etc. The declaration of a major for undecided students within the learning community was compared to the major choices of undecided students in an honors chemistry class. Learning community members were more likely than the honors chemistry course undecided students to officially declare a STEM major. In addition, the retention rate of STEM majors within the program was higher than the rate for students in the honors course. Therefore, building a sense of community and engaging students within the living-learning program resulted in positive outcomes for women students and effectively addressed some of the STEM gender difficulties previously outlined.

Successful Pedagogical Techniques for Women in STEM

Busch-Vishniac and Jarosz (2004) suggest that shifting some emphasis from recruitment and climate issues to both curricular content and instructional methods may yield increases in the enrollment of women in STEM. Research shows that women and men respond differently to the way in which content is packaged and taught (Baxter-Magolda 1989; De Courten-Myers 1999; Jacobs and Rossi Becker 1997). Empirical work in both secondary and postsecondary settings supports theories that suggest females are more interested in topics related to their lives, society, and broader concepts than males (Brotman and Moore 2008). Therefore, adjusting course-level practices to align with these findings may cause certain STEM disciplines to become more attractive for females leading them to diversify by gender.

Researchers have found both biological and social variations across genders in effective learning processes (Bachman et al. 2009). The neuroscience literature shows that structural differences between male and female brains may cause varying cognitive functionalities. According to psychometric tests, males tend to consider facts in isolation, while females integrate pieces of information into larger concepts (De Courten-Myers 1999). A cognitive study by Belenky et al. (1986) indicated that females gain knowledge by accessing other experiences. In essence, they generally begin to understand a concept by first relating it to a personal experience. Jacobs and Rossi Becker (1997) also suggest that women excel in math under pedagogies built from intuition and personal experience. Generalization, contextualization, induction, and creativity all generate a greater likelihood that women will learn math concepts. In summary, these cognitive theories indicate that women tend to approach problems and process information contextually from a personal experience.

Several empirical studies have supported these theories through surveys or observations of classrooms in both K–12 and higher education settings. Research by Campbell et al. (2002) showed that hands-on learning for fourth and eighth graders yielded higher achievement in STEM, especially for females in physical science labs. Instead of typical weed-out introductory courses, increasing hands-on activities early in the course sequence promotes the recruitment and retention of women students (O'Callaghan and Enright Jerger 2006). Small group learning has also been shown to enhance achievement, attitudes, and persistence, regardless of whether the smaller, more engaged group is of mixed genders (Campbell et al. 2002). It facilitates more interaction, greater feelings of acceptance, and more positive expectations, for student participants than the traditional lecture style (Johnson and Johnson 1983), thereby addressing some of the alienation issues sometimes facing women in STEM. Terenzini et al. (2001) compared student learning outcomes between active and traditional learning techniques in engineering schools. They found that students in active learning settings have statistically significant advantages in learning outcomes, specifically in design skills, communication skills, and group skills. Similarly, in a meta-analysis of research on undergraduate education, Springer et al. (1999) found that this collaborative learning style yielded increases in student persistence for STEM fields in particular. In STEM courses, instructors still tend to rely on teacher-centered pedagogies. Students completing a survey in each of their first four semesters of college indicated that science courses typically rely on standard transmission-lecture techniques. Despite having insignificant disparities in ability and performance, deflated persistence for women science students was explained by this teaching method (Dickie et al., 2006). There has been a slow realization among STEM faculty members that instructional methods should be retooled, and interactively designed courses that begin with questions relevant to everyday life have seen more recent success (Seymour 2001).

Utilizing case studies is an example of retooling the curriculum and is an effective pedagogical technique to connect theoretical and practical knowledge (Shulman 1997). For women especially, research shows that contextualizing math and science skills via a practical problem effectually sparks and can sustain a long-term interest in STEM subjects (Halpern et al. 2007). Specifically, stressing the social relevance of science and engineering is a tactic that has proven successful in the recruitment and retention of women. Brotman and Moore (2008) showed evidence throughout the literature that women place a larger importance on conceptual relationships and connections than men, focusing on larger, broader pictures rather than individual details. Similarly, Clewell and Campbell (2002) asserted that effective interventions include using "real life" situations in problem solving and exposing females to role models. Marshall and Dorward (1997) conducted an experiment with undergraduate students to quantitatively determine whether minimal inclusion of biographical information of women scientists had an effect on student perceptions of women in the field. They introduced the biographical information to certain class sections but not to others and surveyed each class's perceptions before and after the course. Results indicated that perceptions of students who were exposed to women scientists shifted away from the notion that science is a male-dominated endeavor. Perceptions of students in the control group did not change over the course of the semester. As such, this experiment showed that classroom practices can in fact shift students' views of the field and perhaps spark interest to pursue further inquiries.

Several other authors cited successes in the engagement of female students when a science or engineering topic was related to a real-world situation. Zastavker et al. (2006) studied how problem-based learning affected outcomes for first year engineering students. Women in their study cited interdisciplinary teaching, or teaching across topics that mimicked real-world situations, as positive sources of learning. A qualitative study of underachieving high school females noted that students were more likely to engage in activities that were made personally relevant. Implications from this work suggest further research on determining how engagement varies with contexts (Thompson and Windschitl 2005).

Finally, Kardash and Wallace (2001) surveyed 922 undergraduates in an assessment of their perceptions about science. Both males and females had similar academic abilities, appreciation for science, interest in pursuing a science-related career, and beliefs that they were academically prepared. However, they differed in their reactions to the pedagogical techniques employed by professors. Men tended to agree that faculty used cognitively based methods of instruction, but women described the instructional method as being teacher-directed. Consistent with other research, women indicated that faculty did not emphasize broad concepts well enough, did not explain topics in a way that made sense intuitively, and did not link new lessons to previously learned subjects. Most importantly, women did not feel that professors created an engaging classroom environment to allow interaction and collaborative discovery.

The engineering curriculum in freshman-level courses can creatively entice students into the field by addressing social relevance and diversity to allow students to place material into personal and historical contexts. Farrell (2002) described creative examples of classes offered by institutions designed specifically to attract women by showing the social value and relevance of math and science. At Rensselaer Polytechnic Institute, introductory courses are offered as studio classes with only thirty-five students as opposed to the traditional large lectures. Each studio used problem-based learning strategies that engaged students with real-world projects. Tufts University taps into students' hobbies to illustrate fundamentals through courses like "Gourmet Engineer." This class demonstrates heat transfer processes via heating food in an oven and has experienced a 40 percent female to male ratio, twice the national average.

Within the science disciplines, Carlone and Johnson (2007) completed a qualitative study analyzing how several women of color successfully navigated through the education pipeline to become scientists. All of these women began with a personal interest in the topic and suggested that the traditional technique of making efforts to spur interest in the hard sciences may not be the most effective approach. Rather, the recommendation resulting from this research emphasizes the relationship between altruism and science. For African American females, in particular, recruitment efforts may be more successful for disciplines such as health sciences or environmental sciences where there is a clear benefit to society.

Developing a greater sense of engagement and application to society has also happened through service learning courses. Markus et al. (1993) examined the impacts of community engagement on political science students' learning and knowledge acquisition. Students were randomly assigned to course sections that either had a community service component or a traditional framework that acted as the control condition. For the community service sections, students were required to complete twenty hours of service of their choosing during the semester. Reflections through course discussions and short papers also accompanied these experiences. Students in the traditional course followed a typical lecture-discussion model that required a longer term paper assignment. In comparing scores on a common midterm and final examination across sections, students in the community service sections performed .29 of a standard deviation (11 percentile points) better than students in the traditional section. This was evident despite beginning the course with no significant differences in academic ability or student characteristics. Similar findings of improved learning through community service requirements have been found in numerous settings (Astin and Sax 1998; Berson and Younkin, 1998; Eyler 1993, 1995; Eyler et al. 1995; Gray et al. 1996; Ikeda 2000; Pascarella and Terenzini 2005; Strage 2000). In comparison to students enrolled in traditional-style courses, students in courses with community service requirements indicate that they are better able to apply concepts from the course to new situations (Kendrick 1996; Markus et al. 1993; Miller 1994).

A Technology for Community course in Colorado combines the societal context and community engagement components to generate successful recruitment of women. The program recognizes recruitment success with women if there is a tangible benefit to society (Jessup et al. 2005). Students provide workshops for the greater Boulder community in this computer science course and learn design and problem-solving skills in concert with a humanized classroom setting. Enrollment patterns in the course are 51 percent female, a demographic that normally only accounts for 9–16 percent of the computer science population. Clearly, having the community engagement component of this course increased the attractiveness for females to enroll. As shown, being able to apply knowledge to new contexts is especially attractive for women students, so offering courses with a community engagement component may be an avenue of increasing women's participation in the STEM fields.

A Strategy to Recruit Women into STEM Fields

Courses and programs that have successfully inspired female enrollment in STEM disciplines through societal contextualization of topics can be used as springboards for recruitment. One potential avenue for accomplishing such a focus is to use the lens of civic engagement to introduce the relevance of STEM topics to societal issues. An educational outcome for this lens would be the connection of STEM-related knowledge with choices and action. As the Association of American Colleges and Universities (2007, 39) indicated, "students should be provided with guided opportunities to explore civic, ethical, and intercultural issues in the context of their chosen fields." Employing civic engagement in introductory or general education classrooms to foster a connection between science topics and civic issues may produce new interests and support enrollment in the sciences among women (NRC 1999).

Historically, civic engagement has been a de-emphasized mission of colleges and universities as institutions have shifted from civic institutions to research machines. However, with the recent resurgence of community involvement on campuses, civic engagement has great potential for problem solving and program planning in institutions of higher education (Checkoway 2000). Several benefits could result from incorporating civic engagement into introductory classes or science courses for non-majors that may ultimately result in increased enrollment by women. According to Sax (1996), the strongest predictor of a woman's enrollment in a STEM graduate field is the pre-college interest in making a theoretical contribution to science. Negative predictors include the following: (1) individuals with the "social activist" personality type; (2) women who are concerned with the "social good" of a career choice; and (3) careers that "make a contribution to society." Based upon this research, introducing science topics through civic engagement may attract a wider population of females into these courses that would not have enrolled previously. As Sax (1996) found, these women still may not pursue a graduate degree in the sciences, but they would be exposed to science topics that could potentially spark an interest for future inquiry—this too should be seen as a success for STEM education. Important additional work should further examine career theory and the entry of women into the STEM workforce or further studies in graduate school.

A second benefit of introducing civic engagement into science courses is the potential for producing a more responsible citizenry from these fields. Students majoring in biology, chemistry, and engineering are the least inclined college graduates to participate politically (Hillygus 2005). Introducing civic engagement into coursework may change that behavior. Prior research on learning preferences for women in STEM fields has driven this notion of incorporating civic engagement into science coursework. The end result may yield dual benefits: (1) a more active citizenry of science students, and (2) a curriculum that is more conducive to female student success, interest, and enrollment in undergraduate science classes.

Science Education for New Civic Engagements and Responsibilities (SENCER) is a national effort to teach science through the framework of complex civic issues and their consequences. These classes can provide a vehicle for studying the relationship between classroom processes and increasing women's confidence and interest in science. Overarching SENCER goals include the following: (1) increase student learning and interest through engagement in STEM courses; (2) help students make connections between material presented in STEM courses to their other studies; and (3) strengthen students' understanding of science and their capacity for responsible work and citizenship (SENCER 2006).

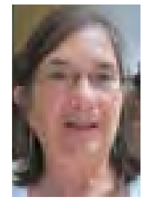
SENCER courses place the teaching of science content within the broader context of educating students to become aware of complex and unresolved civic issues. As research suggests, faculty who participate in these courses have found that when students are engaged with learning that is both intellectually challenging and directly connected to "real world" problems, they become interested in or maintain their interest in STEM fields. The courses have clear learning objectives that can be linked to students' goals for personal and career development and include opportunities to communicate results and use new knowledge for action. In addition, courses apply strategies that emphasize active, inquiry-based learning, and many connect studies to community-based issues and groups. All of these pedagogical techniques are consistent with research on the preferred learning styles of female students. As such, implementing frameworks like SENCER may be an effective model for recruiting additional women into the STEM disciplines.

Weston et al. (2006) completed an extensive, independent multi-year evaluation of the SENCER framework and found that enrollment in these courses had a positive effect on students' views of science. This analysis of 10,000 students enrolled in over three hundred SENCER courses also had significant findings for female students in particular. Females showed greater increases than males overall, and non-science majors showed greater gains than science majors on many of the confidence and interest items, regardless of gender. Over the length of a course, women tended to close the pre-course gap that existed with men for these items. Furthermore, women exceeded men in their perceptions of their ability to apply scientific information to social concerns after completing a SENCER course.

The majority of students enrolled in SENCER courses are females who have taken few science courses (Middlecamp et al. 2006). Since these students exhibit gains in both confidence and interest after taking part in the courses, generating interest in STEM among females through civic engagement may be promising. As this review conveys, research shows that females tend to prefer active and collaborative learning environments in which new material is contextualized into real-world situations. Pedagogies that implement civic engagement frameworks in the classroom align with these preferences and represent a strategy for recruiting women into STEM fields.

About the Authors

David Knight is a Ph.D. candidate in the Higher Education Program at the Pennsylvania State University. His research interests include interdisciplinarity on college campuses from both organizational and curriculum perspectives as well as effective strategies of introducing science topics to non-science majors. As the corresponding author, inquiries about this literature review may be directed to David at dbk144@psu.edu.



Ellen F. Mappen is a senior scholar at the National Center for Science & Civic Engagement. She was the founder and long-time director of the Douglass Project for Rutgers Women in Math, Science, and Engineering at Rutgers University and was the director of healthcare services at the New Brunswick Health Sciences Technology High School. In these positions, she has worked to provide opportunities that encourage women and students of color to enter STEM fields. She holds a Ph.D. in history.

Dr. Stephanie Knight is professor of educational psychology at the Pennsylvania State University. Her research interests include teacher preservice and inservice professional development and classroom processes.

References

Abu El-Haj, T.R.A. 2003. "Practicing for Equity from the Standpoint of the Particular: Exploring the Work of One Urban Teacher Network." *Teachers College Record* 105: 817–845.

America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007. 2007. Pub. L. No. 110-169.

American Association of University Women (AAUW). 1998. "Separated by Sex: A Critical Look at Single Sex Education for Girls." Washington D.C.: AAUW Educational Foundation.

American Competitiveness Initiative. 2006. Washington, D.C.: U.S. Department of Education.

Association of American Colleges and Universities. 2007. "College Learning for the New Global Century." Report by the National Leadership Council for Liberal Education and America's Promise.

Astin, A. and L. Sax. 1998. "How Undergraduates are Affected by Service Participation." *Journal of College Student Development* 39: 251–263.

Augustine, N.R. 2005. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, D.C.: National Academy of Science, National Academy of Engineering, Institute of Medicine, National Academy Press.

Bachman, K.R.O., M.R. Hebl, L.R. Martinez, and A.D. Rittmayer. 2009. "Girls' Experiences in the Classroom." *Applying Research to Practice (ARP) Resources.* www.engr.psu.edu/awe/misc/ARP_WebPages/classroom.aspx (accessed January 12, 2011).

Barber, L.A. 1995. "U.S. Women in Science and Engineering, 1960–1990: Progress Toward Equity?" *Journal of Higher Education* 66(2): 213–234.

Barres, B. 2006. "Does Gender Matter?" *Nature* 442: 133–136.

Baxter-Magolda, M.B. 1989. "Gender Differences in Cognitive Development: An Analysis of Cognitive Complexity and Learning Styles." *Journal of College Student Development* 30(3): 213–220.

R Beichner, J M Saul, D S Abbott, J. Morse, Duane Deardorff, Rhett J. Allain, S W Bonham, Melissa Dancy, and J. Risley. 2007. "Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project," in *Research-based Reform of University Physics*, E.F. Redish and P.J. Cooney. eds. College Park, MD: American Association of Physics Teachers.

Belenky, M.F., B.M. Clinchy, N.R. Goldberger, and J.M. Tarule. 1986. *Women's Ways of Knowing: The Development of Self Voice and Mind.* New York: Basic Books.

Berson, J., and W. Younkin. 1998. "Doing Well by Doing Good: A Study of the Effects of a Student-Learning Experience on Student Success." Paper presented at the meeting of the Association for the Study of Higher Education: Miami, November.

Bhanot, R. and J. Jovanovic. 2005. "Do Parents' Academic Gender Stereotypes Influence Whether They Intrude on Their Children's Homework?" *Sex Roles* 52: 597–607.

Borrego, M.J., M.A. Padilla, G. Zhang, M.W. Ohland, and T.J. Anderson. 2005. "Graduation Rates, Grade-Point Average, and Changes of Major of Female and Minority Students Entering Engineering." 35th ASEE/IEEE Frontiers in Education Conference: Indianapolis, IN, October 19–22.

Brickhouse, N.W. 2001. "Embodying Science: A Feminist Perspective on Learning." *Journal of Research in Science Teaching* 38: 282–295.

Brint, S., A.M. Cantwell, and R.A. Hanneman. 2008. "The Two Cultures of Undergraduate Academic Engagement." *Research in Higher Education* 49: 383–402.

Brotman, J.S., and F.M. Moore. 2008. "Girls and Science: A Review of Four Themes in the Science Education Literature." *Journal of Research in Science Teaching* 45(9): 971–1002.

Buchmann, C., and B. Dalton. 2002. "Interpersonal Influences and Educational Aspirations in 12 Countries: The Importance of Institutional Context." *Sociology of Education* 75: 99–122.

Busch-Vishnicac, I.J., and J.P. Jarosz. 2004. "Can Diversity in the Undergraduate Engineering Population Be Enhanced Through Curricular Change?" *Journal of Women and Minorities in Science and Engineering* 10: 255–281.

Cadinu, M., A. Maass, A. Rosabianca, A., and J. Kiesner. 2005. "Why Do Women Underperform under Stereotype Threat? Evidence for the Role of Negative Thinking." *Psychological Science* 16: 572–578.

Campbell, A., and G. Skoog. 2004. "Preparing Undergraduate Women for Science Careers: Facilitating Success in Professional Research." *Journal of College Science Teaching* 33(5): 24–26.

Campbell, P.B., and J.N. Storo. 1994. "Girls Are . . . Boys Are . . . : Myths, Stereotypes, and Gender Differences." Report for the Office of Educational Research and Improvement, U.S. Department of Education.

Campbell, P.B., E. Jolly, L. Hoey, and L.K. Perlman. 2002. "Upping the Numbers: Using Research Based Decision Making to Increase Diversity in the Quantitative Disciplines." GE Foundation Report.

Carl D. Perkins Career and Technical Education Act of 2006. 2006. Pub. L. No. 109–270.

Carlone, H.B., and A. Johnson. 2007. "Understanding the Science Enterprises of Successful Women of Color: Science Identity as an Analytic Lens." *Journal of Research in Science Training* 44(8): 1187–1218.

Catsambis, S. 1994. "The Path to Math: Gender and Racial-Ethnic Differences in Mathematics Participation from Middle School to High School." *Sociology of Education* 67(3): 199–215.

Cebula, R. J., and J. Lopes. 1982. "Determinants of student Choice of Undergraduate Major Field." *American Educational Research Journal* 19(2), 303–312.

Checkoway, B. 2000. "Public Service: Our New Mission." *Academe Online*, July/August. www.aaup.org/AAUP/pubsres/academe/2000/JA/Feat/chec.htm (accessed January 12, 2011).

Clewell and Campbell. 2002. "Taking Stock: Where We've Been, Where We Are, Where We're Going." *Journal of Women and Minorities in Science and Engineering* 8: 255–284.

Cunningham, C. and M. Knight. 2004. Draw an Engineer Test: Development of a Tool to Investigate Students' Ideas about Engineers and Engineering. Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition. Salt Lake City, Utah, June 20–23. Washington, D.C.: ASEE.

Cunningham, C., C. Lachapelle, and A. Lindgren-Streicher. 2005. *Assessing Elementary School Students Conceptions of Engineering and Technology.* Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition. Portland, OR, June 12–15. Washington, D.C.: ASEE.

Davies, S., and N. Guppy. 1997. "Fields of Study, College Selectivity, and Student Inequalities in Higher Education." *Social Forces* 75(4): 1415–1436.

Daymont, T.N., and P.J. Andrisoni. 1984. "Job preferences, College Major, and the Gender Gap in Earnings." *Journal of Human Resources* 19(3): 408–428.

De Courten-Myers, G.M. 1999. "The Human Cerebral Cortex: Gender Differences in Structure and Function." *Journal of Neuropathology and Experimental Neurology* 58(3): 217–226.

Dickie, L.O., H. Dedic, S. Rosenfield, E. Rosenfield, and R.A. Simon. 2006. "Success and Persistence in Science: The Influence of Classroom Climate." arXiv:physics/0610243v1.

Donald, J.G. 2002.. *Learning to Think: Disciplinary Perspectives.* San Francisco: Jossey-Bass.

Eyler, J. 1993. "Comparing the Impact of Two Internship Experiences on Student Learning." *Journal of Cooperative Education* 29(3): 41–52.

Eyler, J. 1995. "Graduates' Assessment of the Impact of a Full-Time College Internship on Their Personal and Professional Lives." *College Student Journal*, 29: 186–194.

Eyler, J., D. Giles, and J. Braxton. 1995. "The Impact of Alternative Models of Service Learning on Student Outcomes." Paper presented at the National Society for Experiental Education (NSEE) conference: New Orleans, November.

Fadigan, K.A., and P.L. Hammrich. 2004. "A Longitudinal Study of the Educational and Career Trajectories of Female Participants of an Urban Informal Science Education Program." *Journal of Research in Science Teaching* 41: 835–860.

Farrell, E. 2002. "Engineering a Warmer Welcome for Female Students." *Leadership and Management in Engineering* 2(4): 19–22.

Frehill, L., A. Javurek-Humig, and C. Jesser-Cannavale, 2006. "Women in Engineering: A Review of the 2005 Literature." *Magazine of the Society of Women Engineering* 52(3): 34–63.

Geiger, R. 2004. *To Advance Knowledge*. New Brunswick, NJ: Transaction Publishers.

Gilbert, J., and S. Calvert. 2003. "Challenging Accepted Wisdom: Looking at the Gender and Science Education Question Through a Different Lens." *International Journal of Science Education* 25: 861–878.

Goyette, K.A., and A.L. Mullen. 2006. "Who Studies the Arts and Sciences? Social Background and the Choice and Consequences of Undergraduate Field of Study." *Journal of Higher Education* 77(3): 497–538.

Gray, M., S. Geschwind, E. Ondaatje, A. Robyn, S. Klein, and L. Sax, L. 1996. "Evaluation of Learn and Serve America, Higher Education: First Year Report I." Washington, D.C.: RAND Institute on Education and Training.

Halpern, D.F., J. Aronson, N. Reimer, S. Simpkins, J.R. Star, and K. Wentzel 2007. "Encouraging Girls in Math and Science." Report for Institute of Education Sciences Practice Guide, U.S. Department of Education.

Herzig, A.H. 2004. "Becoming Mathematicians: Women and Students of Color Choosing and Leaving Doctoral Mathematics." *Review of Educational Research* 74: 171–214.

Hillygus, D.S. 2005. "Exploring the Relationship Between Higher Education and Political Engagement." *Political Behavior* 27(1): 25–47.

Ikeda, E. 2000. "How Reflection Enhances Learning in Service-learning Courses." Paper presented at the meeting of the American Educational Research Association: New Orleans.

Improving America's Schools Act of 1994. 1994. Publ L. No. 103-382, S 3502.

Jacobs, J. A. 1986. "The Sex-Segregation of Fields of Study: Trends During the College Years." *Journal of Higher Education* 57(2): 134–154.

Jacobs, J. A. 1995. "Gender and Academic Specialties: Trends Among Recipients of College Degrees in the 1980s." *Sociology of Education 68*(2): 81–98.

Jenkins, M., and R.G. Keim. 2004. "Gender Trends in Engineering Education." Paper presented at Frontiers in Education (FIE): Savannah, GA, October 20–23.

Jacobs, J.E., and J. Rossi Becker. 1997. "Creating a Gender-Equitable Multicultural Classroom Using Feminist Pedagogy." In *Multicultural and Gender Equity in the Mathematics Classroom: The Gift of Diversity* (1997 Yearbook), 107–114). Reston, VA: National Council of Teachers in Mathematics.

Jessup, E., T. Sumner, and L. Barker. 2005. "Report from the Trenches: Implementing Curriculum to Promote the Participation of Women in Computer Science." *Journal of Women and Minorities in Science and Engineering* 11: 273–294.

Johnson, D.W., and R.T. Johnson. 1983. "The Socialization and Achievement Crisis: Are Cooperative Learning Experiences the Solution?" *Applied Social Psychology Annual* 4: 119–164.

Kahveci, A. 2006. "Retaining Undergraduate Women in Science, Mathematics, and Engineering." *Journal of College Science Teaching* 36(3): 34–38.

Kardash, C.M., and M.L. Wallace. 2001. "The Perceptions of Science Classes Survey: What Undergraduate Science Reform Efforts Really Need to Address." *Journal of Educational Psychology* 93(1): 199–210.

Kendrick, J. 1996. "Outcomes of Service Learning in an Introduction to Sociology Course." *Michigan Journal of Community Service Learning* 3(1): 72–81.

Kiefer, A.K., and D. Sekaquaptewa. 2007. "Implicit Stereotypes, Gender Identification, and Math-related Outcomes: A Prospective Study of Female College Students." *Psychological Science* 18: 13–18.

Krendl, A.C., J.A. Richeson, W.M. Kelley, and T.F. Heatherton. 2008. "The Negative Consequences of Threat: A Functional Magnetic Resonance Imaging Investigation of the Neural Mechanisms Underlying Women's Underperformance in Math." *Psychological Science* 19: 168–175.

Lattuca, L. R. and J.S. Stark. 2009. *Shaping the College Curriculum: Academic Plans in Context*. San Francisco, CA: Jossey-Bass.

Markus, G., J. Howard, and D. King. 1993. "Integrating Community Service and Classroom Instruction Enhances Learning: Results from an Experiment." *Educational Evaluation and Policy Analysis* 15: 410–419.

Marshall, J.A., and J.T. Dorward. 1997. "The Effect of Introducing Biographical Material on Women Scientists into the Introductory Physics Curriculum." *Journal of Women and Minorities in Science and Engineering* 3: 279–294.

Metz, S.S., and K. Samuelsen. 2000. "Making the Connection Presenter's Guide." Women in Engineering ProActive Network (WEPAN).

Miller, J. 1994. "Linking Traditional and Service-learning Courses: Outcomes Evaluation Using Two Pedagogically Distinct Models." *Michigan Journal of Community Service Learning* 1: 29–36.

National Academy of Engineering (NAE). 2008. *Changing the Conversation: Messages for improving Public Understanding of Engineering*. Washington D.C.: National Academy Press.

National Commission on Excellence in Education (NCEE). 1983. "A Nation at Risk: The Imperative for Educational Reform (Report No. 065-000-00177-2)." Washington D.C.: U.S. Department of Education.

National Research Council (NRC) Committee on Women in Science and Engineering. 1991. *Women in Science and Engineering: Increasing Their Numbers in the 1990s*. Washington, D.C.: National Academy Press.

National Research Council (NRC) Committee on Women in Science and Engineering. 1999. *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Washington, D.C.: National Academy Press.

National Research Council (NRC) Committee on Women in Science and Engineering. 2006. "To Recruit and Advance: Women Students and Faculty in Science and Engineering." Washington, D.C.: National Academy Press.

National Science Board (NSF). 2010. "Higher Education in Science and Engineering." Ch. 2 in *Science and Engineering Indicators: 2010* by the National Science Foundation, 2.1–2.48. Washington D.C.: National Science Board of the National Science Foundation.

Nelson Laird, T. F., R. Shoup, G.D. Kuh, and M.J, Schwarz. 2008. "The Effects of Discipline on Deep Approaches to Student Learning and College Outcomes." Research in Higher Education 49: 469–494.

Nosek, B. A., M.R. Banaji, and A.G. Greenwald. 2002. "Math = Male, Me = Female, Therefore Math ≠ Me." *Journal of Personality and Social Psychology* 83: 44–59.

O'Callaghan, E.M., and N.D. Enright Jerger. 2006. "Women and Girls in Science and Engineering: Understanding the Barriers to Recruitment, Retention, and Persistence Across the Educational Trajectory." *Journal of Women and Minorities in Science and Engineering* 12: 209–232.

Pascarella, E.T, and P.T. Terenzini 2005. *How College Affects Students, Vol. 2: A Third Decade of Research.* San Francisco, CA: Jossey-Bass.

Plumb, C., and R.M. Reis. 2007. "Creating Change in Engineering Education: A Model for Collaboration Among Institutions." *The Magazine of Higher Learning* 39(3): 22–31.

Sax, L. 1996. "The Impact of College on Post-college Commitment to Science Careers: Gender Differences in a Nine-year Follow-up of College Freshmen." Presented at the Annual Meeting of the Association for the Study for Higher Education: Memphis, TN, November.

Scantlebury, K., and D. Baker. 2007. "Gender Issues in Science Education Research: Remembering Where the Difference Lies." In *Handbook of Research on Science Education*, S. Abell and N. Lederman, eds., 257–286. Mahwah, NJ: Lawrence Erlbaum.

Schunk, D. H., and F. Pajares. 2002. *The Development of Academic Self-Efficacy.* San Diego: Academic Press.

Science Education for New Civic Engagements and Responsibilities (SENCER). 2006. "About SENCER: An Overview." www.sencer.net/About/projectoverview.cfm (accessed December 24, 2010).

Seymour, E. 1995. "The Loss of Women from Science, Mathematics, and Engineering Undergraduate Majors: An Explanatory Account." *Science Education* 79: 437–473.

Seymour, E. 2001. "Tracking the Processes of Change in U.S. Undergraduate Education in Science, Mathematics, Engineering, and Technology." *Science Education* 86: 79–105.

Shulman, L.S. 1997. "Professing the Liberal Arts." In *Education and Democracy: Reimagining Liberal Learning in America.* R. Orrill, ed., New York: The College Entrance Examination Board.

Simpson, J. C. 2001. "Segregated by Subject: Racial Differences in the Factors Influencing Academic Major Between European Americans, Asian Americans, and African, Hispanic, and Native Americans." *Journal of Higher Education* 72(1): 63–100.

Springer, L, M.E. Stanne, and S.S. Donovan. 1999. "Effects of Small-group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis." *Review of Educational Research* 69(1): 21–51.

Stake, J. E., and S.D. Nickens. 2005. "Adolescent Girls' and Boys' Science Peer Relationships and Perceptions of the Possible Self as Scientist." *Sex Roles* 52: 1–12.

Steele, C. 2003. "Through the Back Door to Theory." *Psychological Inquiry* 14(3–4): 314–317.

Strage, A. 2000. "Service-learning as a Tool for Enhancing Student Outcomes in a College-level Lecture Course." Paper presented at the meeting of the American Educational Research Association: New Orleans, April.

Terenzini, P.T., A.F. Cabrera, C.L. Colbeck, J.M. Parente, and S.A. Bjorklund. 2001. "Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains." *Journal of Engineering Education* 90(1): 123–130.

Thomas, G. E. 1985. "College Major and Career Inequality: Implications for Black Students." *The Journal of Negro Education* 54(4): 537–547.

Thompson, J.J., and M. Windschitl. 2005. "Failing Girls: Understanding Connections among Identity Negotiation, Personal Relevance, and Engagement in Science Learning from Underachieving Girls." *Journal of Women and Minorities in Science and Engineering* 11: 1–26.

Tiedemann, J. 2000. "Parents' Gender Stereotypes and Teachers' Beliefs as Predictors of Children's Concept of Their Mathematical Ability in Elementary School." *Journal of Educational Psychology* 92: 144–151.

Tobias, S. 1990. *They're Not Dumb, They're Different: Stalking the Second Tier*. Tuscon: Research Corporation.

Valian, V. 2005. "Beyond Gender Schemas: Improving the Advancement of Women in Academia." *Hypatia* 20(3): 198–213.

Weston, T., E. Seymour, E., and H. Thiry. 2006. "Evaluations of Science Education for New Civic Engagements and Responsibilities (SENCER) Project." The National Center for Science and Civic Engagement. www.sencer.net/assessment/pdfs/Assessment/FINAL_REPORT_SENCER_12_21_06.pdf (accessed December 24, 2010).

Whitt, E.J., E.T. Pascarella, B.S. Elkins Neisheim, and B.P. Martin. 2003. "Differences Between Women and Men in Objectively Measured Outcomes, and the Factors that Influence those Outcomes, in the First Three Years of College." *Journal of College Student Development* 44(5): 587.

Zafar, B. 2009. "College Major Choice and the Gender Gap." Federal Reserve Bank of New York Staff Reports, no. 364.

Zastavker, Y.V., M. Ong, and L. Page. 2006. "Women in Engineering: Exploring the Effects of Project-based Learning in a First-year Undergraduate Engineering Program." Presented at the 36th ASEE/IEEE Frontiers in Education Conference. San Diego.

PROJECT REPORT

The Chemistry of Natural Waters

A Partnership between Northland College and the Bad River Watershed Association

Angelena Koosmann
Northland College

Alex Bruns
Northland College

Sharon Anthony
Northland College

Introduction

Northland College is an environmental liberal arts college located in Ashland, Wisconsin. In addition to two, fifteen week semesters, Northland has a May term—a four-week semester where students and faculty focus solely on one course. *The Chemistry of Natural Waters* is a field and laboratory intensive May-term course taken primarily by chemistry, biology, environmental studies, and geoscience majors. Students learn water quality field techniques as well as analytical skills for laboratory analysis of water samples. This course employed service learning, which has been shown to have a positive impact on students' academic learning (Driscoll et al., 1996), improve student satisfaction with college (Astin and Sax 1998), and improve students' abilities to apply their learning to "the real world" (Eyler and Giles 1999).

During May 2010 the Chemistry of Natural Waters partnered with the Bad River Watershed Association (BRWA) to assess water quality on seven tributaries flowing into the Marengo River, about fifteen miles south of Ashland (see maps in Figures 1 and 2). These tributaries were chosen because BRWA citizen volunteers and last year's Chemistry of Natural Waters class found levels of *Escherichia coli* (*E. coli*) that exceed the EPA limit of 235 CFU (colony forming units) (USEPA 1986) downstream of these tributaries on the Marengo River. Our hope was to discover which tributaries contribute to these high levels of *E. coli*. Additionally, we measured pH, dissolved oxygen, chloride, turbidity, and phosphate in order to better characterize the overall water quality in these tributaries. In addition to assessing water quality in the field, another goal of our course was to help the BRWA characterize the reliability of the data gathered by their citizen

FIGURE 1. Map of the Bad River watershed, with the Marengo River watershed highlighted in white. The river flows through sparsely populated and highly agricultural lands.

FIGURE 2. Chemistry of Natural Waters 2010 Sampling Sites. The Chemistry of Natural Waters students sampled seven tributaries of the Marengo River, all accessed by County Highway C. Sampling sites are marked by black circles.

volunteers with LaMotte chemical test kits. For the sake of brevity, only our field measurements of *E.coli* and phosphate will be described in this article.

Sixteen students enrolled in the course Chemistry of Natural Waters in May 2010. The class met formally for eighteen hours a week (see Table 1). On Mondays and Wednesdays students learned some theory but focused mainly on analytical techniques in the lab. On Tuesdays and Thursdays, students met with BRWA representatives, learned field techniques, collected samples, and then analyzed them in the lab. Student evaluation consisted of homework assignments, lab practical exams focusing on accuracy and precision, lab notebooks, and a final group project. Students chose from four group projects: (1) an oral presentation geared to representatives of the BRWA and the Marengo Valley community, (2) a written report for the BRWA detailing our methods and results, (3) a scientific

TABLE 1. Course Schedule for the Chemistry of Natural Waters, 2010.

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	Class/Lab	Field Work	Class/Lab	Field Work	No Class
Afternoon	Open lab	Lab work	Open lab	Lab work	No Class

poster that hangs in Northland's science building, and (4) an article that the BRWA published in their quarterly newsletter.

Methods

We collected grab samples of water in the field and brought them back to the laboratory for analysis. These samples were transported on ice and were analyzed within two hours of sampling. In the laboratory, we measured *E.coli* by combining either 5 mL (for typical conditions) or 2 mL (for turbid samples) of water sample with Easygel Coliscan bacterial growth medium. The resultant solution was evenly distributed in a pretreated petri dish sold by Micrology Labs. The samples were incubated for approximately forty eight hours at 35°C. We used Hach ascorbic acid method 490 and a Hach 2800 spectrometer to measure orthophosphate.

Results

Water Quality Field Samples

PHOSPHATE. Phosphorus is recognized as an important water quality indicator because it is often the limiting nutrient responsible for eutrophication, a situation in which excessive algae growth occurs and ultimately causes water quality degradation (Litke 1999). In rural areas such as the Marengo River Valley, the main sources of phosphorus are non-point sources such as fertilizer, manure, and failing septic systems (Klienman and Sharpley 2003; Carpenter et al. 1998).The benchmark maximum phosphate concentration recommended by the United States Geological Survey (USGS) is 0.1 mg/L4. Phosphate in the seven tributaries sampled was often higher than 0.1 mg/L (of the 32 samples taken from the seven tributaries over six days, 25 had a phosphate concentration greater than 0.1 mg/L). Also, as seen in Figure 3, on May 13, the day of a substantial rain event, phosphate levels exceeded the 0.1 mg/L USGS benchmark at each the five sites sampled.

E COLI. *E. coli* indicates the presence of fecal matter in a water body and possibly the presence of disease causing bacteria and viruses. The EPA limit for *E. coli* is 235 CFU/100 mL (EPA 1986). As seen in Figure 4 for Billy Creek, on sampling days when it did not rain, the *E coli* counts were consistently under the EPA limit. However as depicted in Figure 5, on May 13, 2010, the day of the rain event, *E. coli* exceeded the EPA limit

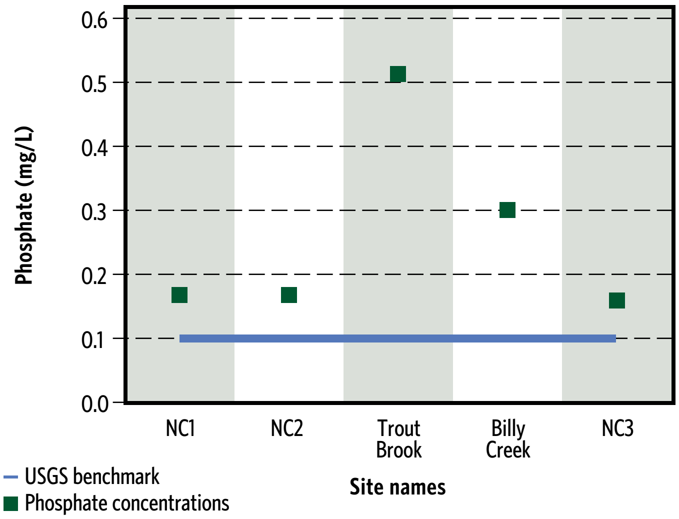


FIGURE 3. **Phosphate Concentrations during a Rain Event. Phosphate concentrations were higher than the USGS benchmark of 0.1 mg/L at all of the five sampling sites sampled during a rain event on May 13th, 2010.**

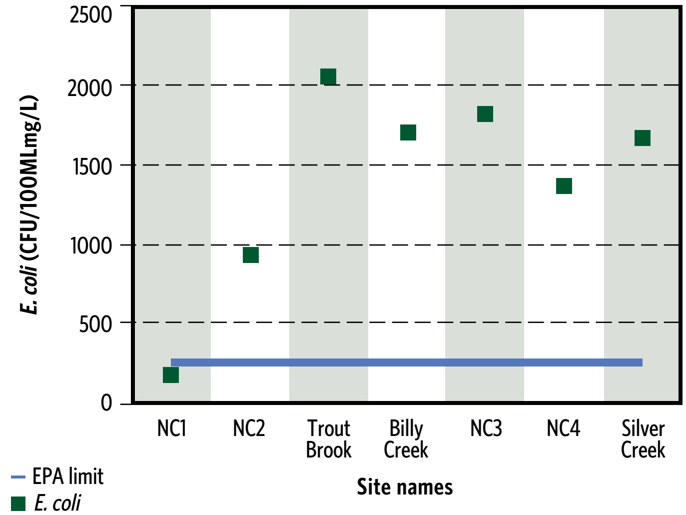


FIGURE 5. ***E. Coli* at the Seven Sampling Sites During a Rain Event. *E. coli* counts were higher than the EPA limit of 235 CFU at six of the seven sampling sites during the May 13th rain event.**

at all sites but NC-1. These results are in line with other studies that have shown that *E. coli* counts rise during rain events due to fecal material from humans, wildlife, and farm animals washing into streams (Kleinheinz et al. 2009).

Discussion

The partnership between the Chemistry of Natural Waters class and the BRWA was mutually beneficial. The data the

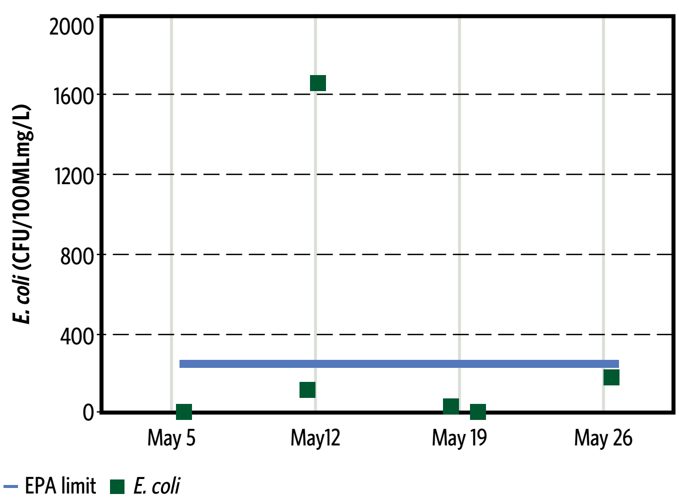


FIGURE 4. ***E. coli* at Billy Creek During May, 2010. *E. coli* measurements at Billy Creek were typically below the EPA's limit of 235 CFU throughout the month of May, 2010. However, *E. coli* counts spiked during a rain event on May 13.**

class collected will be incorporated into the Marengo Watershed Action Plan to be compiled by the BRWA and submitted to the U.S. Environmental Protection Agency. The BRWA also benefited from the partnership because the time students and faculty spent collecting water quality data was translated into matching funds for a National Fish and Wildlife Foundation grant awarded to the BRWA. Because their data were going to be used by the BRWA, students took their work very seriously, carefully learning the analytical skills necessary to gather reliable water quality data. Moreover, the active role taken by the BRWA helped students understand the relevance of their work. The BRWA worked with the faculty member to design the field and quality control projects, trained our students in the LaMotte chemical test kits, attended the final oral presentation, and asked students what they believed the next steps should be. They also published a student-written article about the course in their quarterly newsletter, disseminating our work to the larger community.

Student learning from the project was summarized well in their final poster:

- Phosphate and *E. coli* were well above the EPA suggested guidelines for the rain event on May 13, 2010.
- Continued sampling of the Marengo River Watershed tributaries with multiple rain events is needed for further analysis.

The work of the class is being continued throughout the summer and 2010/2011 school year with funds from a GLISTEN (Great Lakes Innovative Stewardship through Education Network) grant. Two students from the Chemistry of Natural Waters class are continuing to monitor the water quality on the seven tributaries sampled by the class. Depending on their results, next year's Chemistry of Natural Waters students will likely sample the water quality at several points along the most problematic tributaries in an effort to pinpoint the sources of the high phosphate and *E. coli* measured this spring.

About the Authors

Angelena Koosmann and *Alex Bruns* are both Environmental Chemistry majors at Northland College. In the summer of 2010 they were funded by GLISTEN to work with Northland College and the Bad River Watershed Association.

Dr. Sharon Anthony teaches chemistry and environmental science at Northland College. Her teaching and research interests include atmospheric chemistry, climate change, water quality, and sustainable agriculture. She has served as a SENCER leadership fellow since 2009. She is the corresponding author for this article: Sharon Anthony, Northland College, 1411 Ellis Ave., Ashland, WI 54806; 715-682-1803; santhony@northland.edu.

References

Astin, A.W., and L.J. Sax. 1998. "How Undergraduates are Affected by Service Participation." *Journal of College Student Development* 39(3): 251–263.

Carpenter, S., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. "Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen," *Issues in Ecology* 3: 600–601.

Driscoll, A., B. Holland, S. Gelmon, and S. Kerrigan. 1996. "An Assessment Model for Service-Learning: Comprehensive Case Studies of Impact on Faculty, Students, Community, and Institutions." *Michigan Journal of Community Service Learning* 3: 66–71.

Eyler, J.S. and D.E. Giles Jr. 1999. *Where's the Learning in Service-Learning?* San Francisco, CA: Jossey-Bass, Inc.

Kleinheinz, G.T., C.M. McDermott, S. Hughes, and A. Brown. 2009. "Effects of Rainfall on *E. coli* Concentrations at Door County, Wisconsin Beaches." *International Journal of Microbiology*. doi:10.1155/2009/876050.

Kleinman, P.J.A., and A.N. Sharpley. 2003. "Effect of Broadcast Manure on Runoff Phosphorus Concentrations over Successive Rainfall Events." *Journal of Environmental Quality* 32: 1072–1081.

Litke, D.W. 1999. "Review of Phosphorous Control Measures in the United States and Their Effects on Water Quality." U.S. Geological Survey Water-Resources Investigations Report 99-4007.

U.S. Environmental Protection Agency (EPA). 1986. "Ambient Water Quality Criteria for Bacteria." Report Number EPA440/5-84-002. United States Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C.

PROJECT REPORT

Multidisciplinary Engagement of Calculus Students in Climate Issues

Thomas J. Pfaff
Department of Mathematics, Ithaca College

Ali Erkan
Department of Computer Science, Ithaca College

Jason G. Hamilton
Department of Environmental Studies and Sciences, Ithaca College

Michael Rogers
Department of Physics, Ithaca College

Introduction

These days essentially every college student has heard at least something about Earth's warming climate. However, few can articulate even the most basic scientific details, and even fewer have any experience dealing with actual data or calculating anything related to climate change. Over the past decade, there has been an increasing call for scientists to change the types of problems they work on and to reconsider how they address these problems (Palmer et. al., 2005; Lubchenco 1998). However, STEM (science, technology, engineering, and math) education is not keeping up with this new societal need (NRC 1999). The more our students understand about the climate challenges facing humanity, the more likely they are to be civically engaged with the topic. Furthermore, they will be better able to analyze critically the proposed responses and pending legislation and be able to come to their own independent judgments concerning solutions. Or, as put by the National Research Council (NRC 1999), developing an integrated and place-based understanding of the threats facing humanity and the options for dealing with them is a central challenge for promoting a transition toward sustainability.

Responsible civic engagement and promotion of sustainability requires some quantitative skills. Yet,

> [O]nly a small part of the education needed to attain control over numbers can be found in the typical mathematics curriculum. That is because skills in complex counting and data analysis, like many other aspects of numeracy, . . . rarely find a place in the standard calculus-oriented mathematics progression (Orrill 2001).

It is clear that for the majority of students, math skills taught without meaningful context are "devoid of meaning and utility" (Orrill 2001), yet this is precisely how much math is traditionally taught. Here we provide an example in which fundamental calculus tools and concepts are taught using an analysis of changes in Arctic sea ice brought on by human-induced climate change. By addressing the loss of Arctic sea ice, we introduce issues related to climate change and sustainability into calculus, thereby providing meaningful context for the skills they are learning, which is in many ways similar to the projects that (Donnay 2008) uses in a differential equations course. The project here uses curve fitting of real-world data and (Fetta 2003) also gives examples of using curve fitting to address environmental issues, but doesn't directly address a civic engagement component. This project is part of a larger multidisciplinary teaching module (Hamilton et el. 2010, MSE 2010), but may be used as a stand-along project in a calculus course. Introducing curriculum enhancements such as this into introductory calculus courses has the potential to impact large numbers of students because of the large number of courses taught in both high schools and colleges across the country.

The Project

In a traditional introductory calculus course at the point in the semester when students could successfully take derivatives of polynomials and locate max/mins and inflections points, we introduced the sea ice exercise. The learning objective of the exercise was to teach students how to apply these concepts in real world contexts with meaningful units. We have found that using real data and Microsoft Excel as a curve fitting tool is an effective way of incorporating interesting issues into calculus in a number of different ways (Pfaff, in press). We did the exercise as a homework assignment giving the students one week to complete partly because the responses needed to be typed, but it can also be done in class either individually or in groups. It takes about five minutes to grade each project. After students were introduced to the basic concepts, they were given the following instructions:

1. Using Excel curve fitting routines, find two models, E1(x) and E2(x), by Excel curve fitting with output sea ice extent and input month for the 1980 and 2008 sea ice extent data.
2. Use your models to find the maximum and minimum sea ice extent during this time period. Summarize your results in a few sentences for each model and discuss any differences (max, min, month of max/min, time between max/min, etc.) between the models.
3. Use your models to find the month of fastest melting of sea ice. Summarize your results in a few sentences for each model and discuss any differences.
4. In a few sentences discuss how your results might relate to impacts on polar bear habitat.
5. Please turn in a typed report summarizing your findings.

In the course, students were taught how to use Excel for curve fitting during the third week and they were not expected to have previous knowledge of Excel. To ensure a minimum level of proficiency, students fit a dozen data sets over the semester. Curve fitting with Excel is accomplished by first creating a scatter plot and then using the trendline dialog box (a standard feature in Excel). Students were given a quick fifteen-minute demonstration on curve fitting with a few general guidelines on choosing a curve, which is mostly done by visually observing the fit of curves to the data. During the demo, they were told that, in general, the closer the value of R^2 is to one the better the fit. However, increasing the power of a polynomial fit will always raise the value of R^2 because there is an extra variable available for fitting the data. Hence, raising the power of a polynomial should only be done if there is a reason; this can be as simple as there is a better visual fit. Interested readers are referred to almost any general statistics book for more details about R^2. As a further benefit, having students fit data seems to aid their understanding of functions in general. For example, when they first start, students think that any concave up increasing data set should be fit with an exponential function. They soon realize that this is not the case, and discover the difference between exponential and polynomial growth. After the short demo, students were allowed to use the rest of the fifty-minute class to work on fitting the dozen data sets with curves; whatever they didn't finish was completed for homework.

Due to this experience in curve fitting it was expected that students could do part 1 of the assignment on their own. If this assignment were the only time students would encounter curve fitting in the course, instructors could start the project in a lab class to help students through part 1 or they can show students how it is done and provide them with the curves. Instructors interested in doing this type of project should spend an hour getting comfortable doing curve fitting with Excel themselves. In general, learning to curve fit in Excel is no more difficult than learning graphing techniques with a Texas Instrument TI 83/84 calculator, which by the way, will also do curve fitting.

Sample Results

Figure 1, created for this project, shows the graph of Arctic sea ice extent in million square kilometers by month for 1980 and 2008. It also has a sixth degree polynomial fit by Excel for both years. Notice that while 1980 is a visually reasonable fit, the 2008 fit does not reach the minimum and hence has a smaller R^2 value. We should note that students don't need calculus to find the maximum and minimum ice extent since they can get this information directly from the data. Still this is a useful calculus exercise because in this setting the data have a rich context and allows the students to explore real numbers with units. Furthermore, it allows students to check their results by comparing the results from the calculation with results found empirically. Calculus tools do provide an advantage over simple empirical estimates of melting rate. In other words, the inflection point here has an important interpretation.

To give students a chance to explore the concepts and to work with data presentation, we kept directions to a minimum. A summary of the type of results that we would ultimately like to see are shown in Table 1 (note that students were using the TI 83/84 solve function to find when the first and second derivative were zero), but most students didn't provide this much information; more importantly they missed important comparisons. The results from students projects reported below are from two Calculus I courses given in the fall of 2009, with a total of forty-one students and data from forty reports. The students' majors represent a cross section of the campus with no single major comprising more than 15 percent (exploratory was the largest) of the group.

TABLE 1. Summary of Results from Analyzing the Curves in Figure 1

	1980	2008
Maximum	16.13 M km²	15.11 Mkm²
Maximum Location	X = 2.59	X = 2.26
Minimum	7.86 Mkm²	5.40 Mkm²
Minimum location	X = 8.79	X = 8.80
Fastest ice loss	2.20 Mkm²/month	2.84 Mkm²/month
Melt period	6.20 months	6.54 months

Note: Mkm² = million square kilometers

Based on knowing that the climate is warming, we expect less ice in 2008 compared to 1980 but notice that while there is a 1 Mkm² (million square kilometers) difference in the maximums, there is a 2.5 Mkm² difference in the minimums. Further, the 2008 curve is an overestimate of the minimum. Of the forty reports only seventeen commented on the difference between the maximum and minimum of the two years.

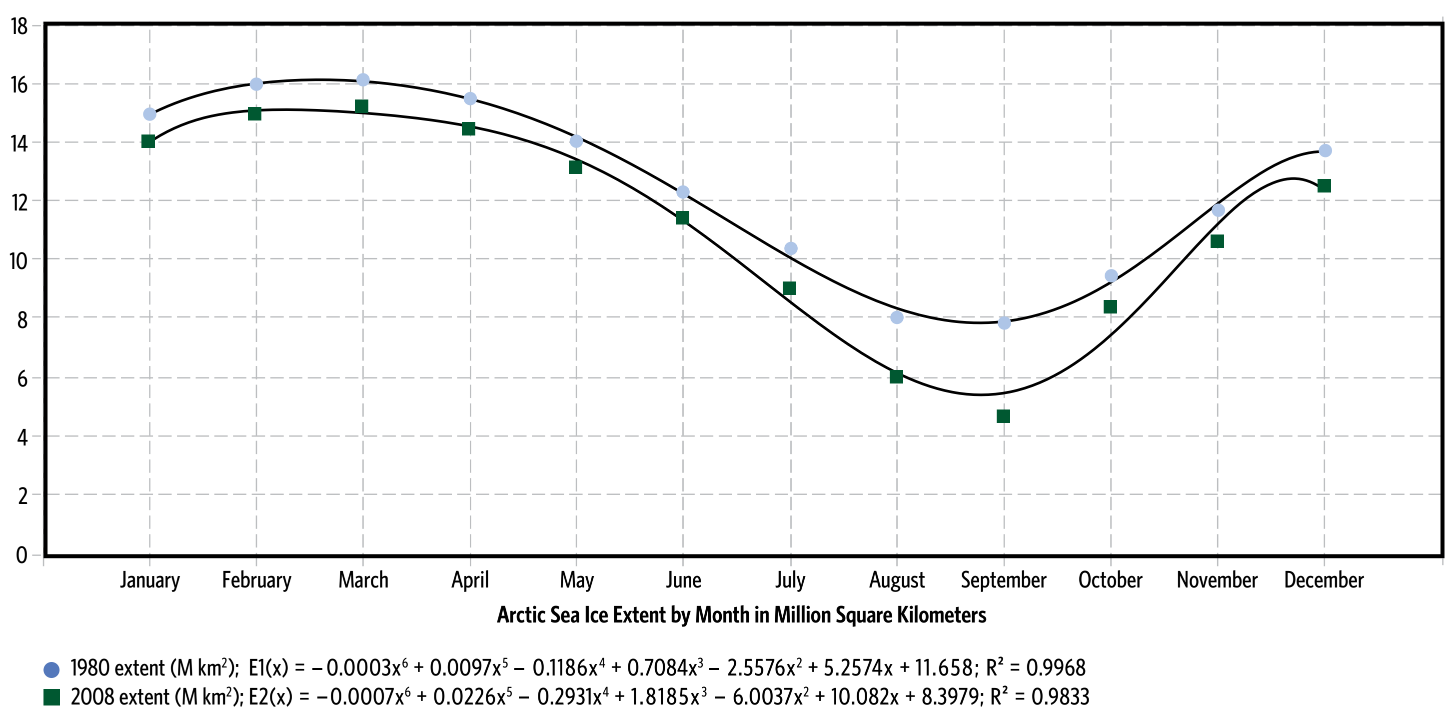


FIGURE 1. Excel curve fits, using the trendline option for a scatter plot, to Arctic sea ice extent in million square kilometers for the years 1980 and 2008. Data from the National Snow and Ice Data Center (ftp://sidads.colorado.edu/DATASETS/NOAA/G02135). M km² = million square kilometers

In fact, only twenty-seven reports actually provided the maximum and minimum amounts of ice, although thirty-eight did report the date of occurrence of the maximum and minimum. None of the reports noted that the 2008 curve gave an overestimate of the minimum.

In 2008, the fastest melting rate is more than half a Mkm^2 per month faster than in 1980 and occurs roughly twenty days later. Only six reports provided the melting rates and only seven reports made any comment about the differences in melting rates, although thirty-nine did provide the date of the inflection point. Furthermore, none of the seven students noted that difference in melting rate might be an important difference. To be fair, the directions asked specifically for the month of fastest melting and not the rate, but we hoped that finding the rate would have been something calculus students would do automatically without being specifically prompted. Our sense is that the students perceive the inflection point only as a place where concavity changes and do not realize that it is also the place, in this context, where ice is melting the fastest. The fact that they didn't suggests that they are still viewing the data as abstract numbers with no real meaning instead of actual data that provide important information about our world. The directions did direct students to calculate a melt period (time between max and min) and while seventeen students reported something about the melt period, often just statements of about six months, only two actually reported that the melt period in 2008 is about ten days longer than in 1980.

These results are somewhat disappointing but not surprising as students don't often encounter projects like this in calculus courses where a little curiosity can go a long way. It is clear that students need more guidance in the instructions if they are to more fully explore the richness of the example. In particular, we need to specifically ask them to compare fastest melting rates as well as to guide them on making valuable comparisons in general. Clearly the written directions were insufficient and possibly some in class discussions about the project will help. We will be using this project in the future and possibly providing the students with a grading rubric for the project will improve their work. This was the first time we used this data and project, and so we were generous in our grading as this was only part of a 5 percent project grade that included the curve fitting of numerous data sets mentioned above and similar questions involving those curves. It is worth noting that when grading this project that not all students will use a 6th degree polynomial, but those lower degree polynomials will give results that are close. Hence, we grading these students may lose some points for a poor choice of curves, but they can still do the analysis with their curves.

Multidisciplinary Connections

By itself, this project can be used to enhance learning and engagement in a calculus class, but we have experimented with further enriching the student experience by linking the project to similar projects in courses from other disciplines. For example, the fact that at the inflection point the ice is melting at a rate of half M km^2 per month faster in 2008 should have students asking the question "why?" and "what does this mean?" One explanation for this difference came from students in a thermodynamics course using feedback loops and albedo (reflectivity). In short, the more the white ice melts and dark water is revealed, the more energy is absorbed to melt ice away. Students might also inquire as to how this loss of ice will impact polar bears. Ecology students informed the class that polar bears hunt seals by waiting for the seals to come up to breathing holes in the ice. The fact that there is less ice means that polar bears have a smaller habitat. Of course, students might also ask about how this data is obtained. Satellite images were processed by students in a data structures course identifying dark and light areas to get estimates of total ice. Thus, the richness of this project potentially extends well beyond the calculus class. Note though that this linking of projects is done by collaborative curriculum development and by saving reports from the other courses to be used at other times (MSE 2010). To be clear, the students in the calculus course were not taking these other courses and that the material here can be used in a typical calculus course.

Although some students may not be moved by the plight of the polar bears because it is so far beyond their direct experience or concern, this is just one example of the impacts of global ice melt. Another example comes from the village of Newtok in Alaska. This entire village must be relocated because the loss of permafrost has allowed the banks of the river to erode (Ansari 2009). Still other examples can be found with the glaciers of the Tibetan Plateau. These glaciers are responsible for supplying water to about two billion people and the Tibetan Plateau is warming up twice as fast as the global average. Once these glaciers are gone so is the water supply (Lamar 2010). One can mention these issues in as little as 10 minutes and still have an impact.

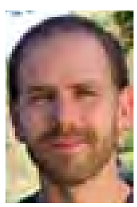
Conclusions

Obviously, the goal of a calculus course is to teach calculus. This assignment provided a rich and meaningful context to aid students in learning standard calculus content, but also provided a natural opportunity for many follow up discussions that served to increase student engagement. On course questionnaires, when students were asked what was the most interesting thing they did in the course, 65 percent of the students chose the applied content. As one student remarked, "The sea ice report, because it was so real life and applied to polar bear's habitats." After doing calculations with real data on sea ice extent, this type of information is more real and immediate to students. At the same time the use of rich and relevant content provides insight into calculus and general quantitative skills. For example, as we noted, students appear to think of inflection points only in terms of concavity change. It is our goal that by teaching traditional calculus with real and relevant examples students will become more engaged citizens.

Acknowledgments

This work was supported by the NSF grant DUE-0837721, Multidisciplinary Sustainability Modules: Integrating STEM Courses.

About the Authors



Thomas J. Pfaff (tpfaff@ithaca.edu) is an associate professor of mathematics at Ithaca College. His main teaching interest is incorporating sustainability into the courses he teaches. He maintains a page of sustainability curriculum materials at www.ithaca.edu/tpfaff/sustainability.htm.

Ali Erkan is an associate professor of computer science at Ithaca College. His Ph.D. work focused on the application of hard real-time systems scheduling algorithms for the coordination of transmissions in wireless networks. His research interests includes the exploration of wiki based systems as a tool to quantify the extent of pedagogically significant factors which have historically been studied in qualitative terms. His home page is at faculty.ithaca.edu/aerkan.

Michael "Bodhi" Rogers is an associate professor of physics at Ithaca College. He has a Ph.D. in physics and a Masters in archaeology, both from Oregon State University. Rogers' primary scholarly interests are Astronomy and Physics Education Research and Archaeological Geophysics.

Jason Hamilton is an associate professor and founding faculty member of the newly formed Department of Environmental Studies and Sciences at Ithaca College. He has a Ph.D. in computational quantum mechanics and a Ph.D. in physiological plant ecology, both from the University of California, Santa Barbara. A global change biologist, Hamilton has worked to develop theories and practices of sustainability and sustainability education.

References

Ansari, A. 2009. '*Climate Change' Forces Eskimos to Abandon Village.* articles.cnn.com/2009-04-24/tech/climate.change.eskimos_1_climate-change-indigenous-communities-eskimos?_s=PM:TECH (accessed September 3, 2010).

Donnay, V. 2008 Ordinary Differential Equations in Real World Situations. SENCER. http://www.sencer.net/resources/pdfs/Models_Print_Web_2008/Mathematical_Modeling_PDF.pdf (accessed Nov 23, 2010).

Fetta, I.B. 2003. "Using Real-World Data to Understand Environmental Challenges." In *Environmental Mathematics in the Classroom*, B.A. Fusaro and P.C. Kenschaft, eds., 11–28. Washington D.C.: The Mathematical Association of America.

Hamilton J, et al. 2010. "Multidisciplinary Collaborations in the Traditional Classroom-Wrestling with Global Climate Change to Improve Science Education." *Transformations: The Journal of Inclusive Scholarship and Pedagogy*, 21(1): 89–98.

Larmer, B. 2010. "The Gods Must be Furious." *National Geographic*: 217(4), 66–79.

Lubchenco, J. 1998. Entering the century of the environment: A new social contract for science. Science, 279. 491–497.

Multidisciplinary Sustainability Education. "Multidisciplinary Sustainability Modules: Integrating STEM Course." www.ithaca.edu/mse (accessed October 7, 2010).

National Research Council. 1999. Our Common Journey: A Transition Toward Sustainability. National Academy Press. http://books.nap.edu/books/0309067839/html/index.html.

Orrill, R. 2001. "Mathematics, Numeracy, and Democracy. In *Mathematics and Democracy: The Case for Quantitiative Literacy*, L.A. Steen, ed., xiii–xx. Princeton, NJ: National Council on Education and the Disciplines, The Woodrow Wilson National Fellowship Foundation.

Palmer, M.A., et al. 2005. "Ecological Science and Sustainability for the 21st Century." *Frontiers in Ecology and the Environment* 3: 4–11.

Pfaff, T. (in press). "Educating Students about Sustainability while Enhancing Calculus." PRIMUS *(Problems, Resources, and Issues in Mathematics Undergraduate Studies).*

PROJECT REPORT

Mud, Muck, and Service

Action Research on Direct and Indirect Service Learning in Ecology

W. Lindsay Whitlow
Seattle University

Sara Hoofnagle
Eckstein Middle School

Introduction

As service learning (SL) becomes more prevalent in university courses, the relative proportion of courses in the scientific disciplines has not kept pace (Furco, 2001). In many cases, an understandable challenge is simultaneously introducing a thorough, often rigorous, canon of new material while working to provide opportunities for students to apply that material to issues in local communities (Sherman and MacDonald 2009). The premium placed on expertise in scientific endeavors, especially those that can address local issues with sufficient depth, tends to limit students' abilities to contribute through their academic knowledge until upper-level courses (Reardon, 1998). And, by that point in their academic careers, many science students are dedicated to preparation for professional or graduate schools that demand further material and time that dissuades instructors from embarking on the endeavor (deKoven and Trumbull 2002). This said, there have been numerous excellent examples of SL successfully applied across a wide variety of science and engineering programs (e.g., NSTA 2009; Draper 2004, Haines 2003). Thanks to these efforts, and honest recognition of the challenges, there is no reason why the sciences cannot increase the prevalence of these opportunities for students in the future (Deegan et al. 2009). Most important to the concept of SL, these opportunities represent not distractions from other requirements, but enhancements to existing curricula.

In this context, ecology and environmental sciences have traditionally offered the greatest opportunities for SL in the sciences (Leege and Cawthorn 2008). Due to the identifiable needs in local communities for work on multiple types of environmental issues, there is much support for collaboration from potential community partners (Brubaker and Ostroff 2000). There is often considerable enthusiasm from students in these courses who often arrive with volunteer experiences or dedication to environmental causes. In some cases, the challenge for ecology courses becomes identifying the most fruitful collaborations for SL that can be most effectively blended with the course material beyond caring for the environment in a general way. A true benefit of these collaborations is the establishment of long-term relationships that can lead to real progress addressing critical local environmental issues.

The focus of this action research was to test the viability and contributions, defined broadly, of two types of SL incorporated into the ecology course at Seattle University.

Project-based Service-learning Model in Ecology

An effective SL approach for the ecology course is the project-based model because it enables students to provide community partners with useful data and research reports while retaining greater ability to provide advice to students on research methods. The project-based SL model involves students working together, often in teams, on a small set of activities with a small set of community partners. These projects sometimes have time constraints during the course to enable more than one project. The goals of these projects are often specifically defined through collaboration between the community partners and the class. In other courses, the placement-based approach is highly effective, where students can individually manage time and relationships with more community partners associated with a course. The technical requirements associated with learning ecological field and laboratory tools and techniques places a premium on insuring students receive sufficient advising. These technical requirements are also important because the projects' goals are defined through identifying potential overlaps between community partners' research needs and student research capabilities. In addition, by focusing the students on two research sites, students have the opportunity to conduct research that is comparable amongst other class members.

Two approaches to service learning in ecology were compared through courses that employed indirect or direct models (Coomey and Wilcenski 2005; Kaye 2004). Indirect SL in the sciences frequently involves data collection by students to be shared with a community partner, with the data often being useful but not essential to the partner, given the students' level of research experience. Direct SL in the sciences can involve students working hand-in-hand with members of the community to expand the data collection experience into opportunities to interact and learn more immediately the purpose of their work (e.g., CSU 2010; OSU 2010).

Indirect Service Learning in Ecology

The indirect model of SL in this course involved students providing data and research reports to the community partners, but interactions with the partners was limited to initial site visits. The primary research sites for the course are Seward Park and the Duwamish River, and community partners have been willing to collaborate on finding appropriate projects for ecology students. The indirect model was utilized in fall and spring quarters.

Seward Park is a remnant Pacific Northwest old-growth forest in southeast Seattle. Our community partners are: Seattle City Parks and Recreation (Urban Forestry), Washington Audubon (Environmental Learning Center), and Friends of Seward Park (a neighborhood group). All three partners have significant interests in forest restoration, and collaborate with one another on projects throughout the park. Through conversations with these partners, they identified the valuable products from ecology student research to be increased understanding of the forest dynamics and baseline assessments of sites prior to restoration projects. Hence, students were encouraged to explore widely in their ecological hypotheses. Completed research reports and data were delivered to the partners.

The Duwamish River is a significantly altered waterway encompassing the Port of Seattle and an EPA Superfund site in south Seattle. Our primary community partner is People for Puget Sound (PFPS), who manage several marsh restoration sites along the lower river. Similar to Seward Park, conversations with PFPS identified valuable student research on increased understanding of river dynamics. Of particular importance for student projects were quantifying pollution levels across habitats and organisms and assessing the success of the restoration efforts in the marshes. Students were again encouraged to explore widely, and many of the marshes had nearby restored and unrestored areas ideally suited for ecological comparisons. Completed research reports and data were delivered to the partners.

To expedite sharing student reports and data, the ecology course has a public website with links to the community partners: Seattle University Creative Collaboration on Terrestrial and Aquatic Scientific Hypotheses (SUCCOTASH) . The site allows students to share their work with the partners and the general public. All the reports are organized by quarter with downloadable pdfs.

Direct Service Learning in Ecology

The direct model of SL in this course involved partnering with Summit High School, an alternative K-12 school in the Seattle School District, to guide high school students in participating in research projects designed by the ecology students. The direct model was utilized only in spring quarter.

Through collaboration with the science teacher at Summit, we generated a plan for having our students work together. After the ecology students initially visited the Duwamish River sites conducting class research projects, they proposed individual research projects as in fall quarter. In this case, their proposals were organized to form five teams made up of students with similar research projects. Then, the initial visit to Summit High by the ecology students involved introducing the high school students to the Duwamish, and describing the five research teams they could work with. By the second visit, the high school students had selected their preferred research teams, so the college students introduced their new colleagues to the research tools and methods they would be using in the field. The third week of the collaboration was an all day field research session at one of the marsh sites, where the teams worked on their projects, collecting and analyzing multiple samples. Afterwards, our partner from People for Puget Sound guided an additional invasive plant removal and shore clean up activity. For the final visit to Summit, the ecology students brought laptops with the team data, and each team worked together to give presentations on their results.

Methods

To evaluate the contributions of service learning in an ecology course, the course was compared between two quarters: (1) Fall quarter 2007 when the SL component was solely the indirect model, and (2) Spring quarter 2008 when the SL component included both indirect and direct models. Responses to a pre- and post-course survey, grades, and written feedback were used to compare these courses.

Ecology Course Overview

Ecology is offered in the Biology Department and is a requirement of all biology majors. It also meets a course requirement within the environmental studies major. Hence, all of the students are from these two majors, and most of them are seniors. The class size is kept small because of equipment availability, access to sites, and intensity of research and advising. Due to this, the course is offered every fall and spring.

While the syllabus is modified for improvement routinely, the course follows a similar structure every quarter. During the three one-hour lectures each week, major concepts in ecology are covered. The concepts were the same for the quarters compared. During the four-hour laboratory every week, students have the opportunity to learn ecological field techniques, and then apply those techniques with concepts from lecture to generate hypotheses to test through individual research projects. The first lab of the quarter is often introductory, with research on campus and an opportunity to learn appropriate data analysis procedures. Generally, three weeks are spent at each field site, with the first week dedicated to introducing methods and tools through a class research project, and the second and third weeks for individual projects. The last lab of the quarter is the symposium where students present talks in the form of scientific conferences on one of their individual research projects. If there are remaining weeks in the quarter, those labs are dedicated for analysis of collected samples or data.

There are four major assignments in the course. The students submit research proposals for each independent project that must include a specific hypothesis, methods, and relevant background. After each project, students submit research reports in the form of manuscripts for major ecological journals. Students select one of their projects to present at the symposium, and submit their presentation in electronic form. Students complete a natural history project describing ecological information on ten species at a local site. In addition, there is a midterm and final exam.

Differences between Quarters

During the fall quarter (n = 15), the indirect SL model was utilized. During the spring quarter (n = 17), both the indirect and direct SL models were utilized. In addition, there were other aspects of the fall course that differed from the spring. Every Friday lecture session was dedicated to discussing relevant ecological papers, and teams of students rotated through responsibility for guiding discussion. After the first research paper on Seward Park forest ecology was submitted, students participated in a thorough peer review process where each student anonymously reviewed two papers, and those reviews were graded. In spring quarter, paper discussions were superseded by visits to Summit High, and insufficient time was available for peer reviewing.

Pre-course Survey

On the first class day for both courses, students responded to a set of questions designed to determine their prior knowledge and interests in a set of topics related to course material and upcoming work (see Appendix). The initial questions identified the student's major, year in school, and reason for taking the course. The remaining questions asked students to evaluate themselves on a scale from strong (5) to weak (1) on their backgrounds, understanding, and interests. The first set of questions focused on ecology and biology, in general. This set was intended to determine the class' incoming knowledge. The second set focused on research, field research, and independent research. This set was intended to determine the class' incoming perspectives on research. The third set focused on service, natural history, writing, and communication. This set was intended to determine the class' broad prior experiences. Mean values for each question were calculated per class.

Post-course Survey

On the last day of class for both courses, students responded to the same set of questions as the pre-course survey. The questions on ecology and biology background were removed since the goal was no longer to establish prior perceptions but any changes in understanding or interests. Mean values were again calculated for each question per class. Also, mean differences in values from pre- to post-course surveys were calculated to determine whether understanding or interest in the array of topics and concepts had increased or decreased. By comparing the changes in mean values of understanding and interest between fall and spring quarters, this approach enabled a measure of the contribution of direct SL to the course.

Grades

Final grades from fall and spring quarters were compared by examining differences in the grade distributions across all students in the classes. While direct SL may not be focused specifically on improving grades, ultimately they are the measure by which students are formally evaluated. Hence, this comparison could enable another measure of the contributions of direct SL. Also, mean numeric grades on specific assignments were compared between quarters. These assignments were selected based on the differences in field research experiences due to involvement of the Summit High class and the time dedicated to that activity versus alternative writing exercises.

Feedback

While the survey form requested additional feedback comments, a more successful approach for generating feedback on the Summit High direct SL activity was provided by their teacher. Her survey asked the SU students to rate the project from excellent (5) to poor (1) across an array of components: enjoyment of overall project content, clear project guidelines, interaction with Summit students, field trip, educational experience, organization, and preparedness. The results from this survey enabled assessment of spring quarter students' opinions on the direct SL project. Also, the survey asked for three highlights or suggestions from the students, and these were interpreted. In addition, a separate survey asked four questions of the Summit students: (1) describe why you selected this SL experience; (2) describe the activities that you participated in during this SL experience; (3) what did you learn from the SL experience? (4) describe how you made a difference in the lives of other people. Through this survey, the value of the SL project for the Summit students could be interpreted.

Statistics

Survey results and grades were compared between the fall and winter quarters to examine differences in student perceptions and performance associated with experiences in indirect and direct service learning. To analyze perception differences, mean responses on the survey scale (1–5) were compared for each question between quarters using Analysis of Variance (ANOVA) with academic term and question as fixed factors to enable comparisons both across terms and among questions. Tukey post-hoc comparisons were made where appropriate. To analyze performance differences, mean grades on five assignments were also compared between quarters using ANOVA. Frequency distributions of final grades between quarters were compared using chi-square analysis.

Results and Discussion

Pre-course Survey

Results from the pre-course surveys show similar backgrounds, understanding, and interests among the students in fall and spring quarters (Figure 1). Students indicated they had relatively little background and understanding of ecology, but higher interest. In a similar vein, they had less background

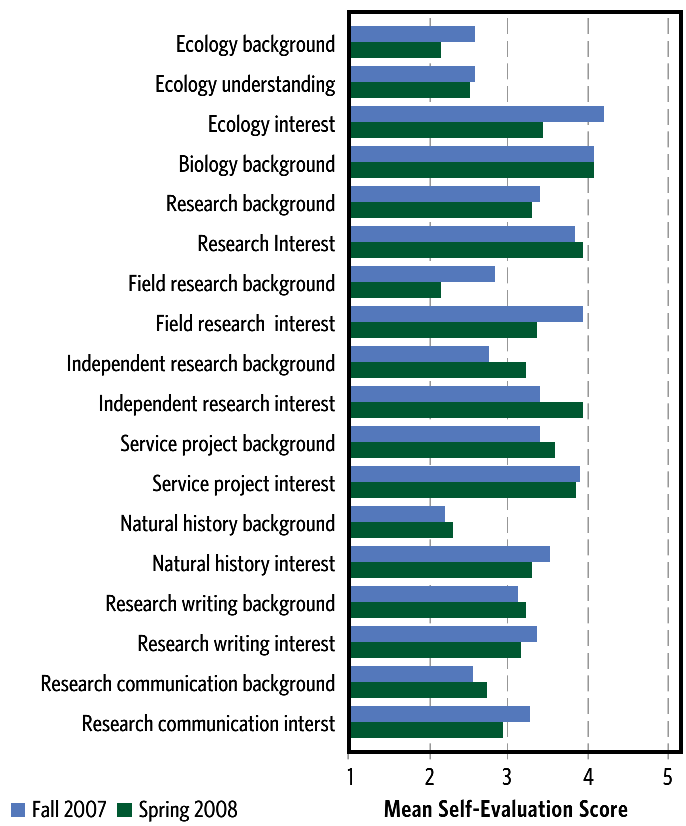


FIGURE 1. Similar results in pre-course surveys of backgrounds, understanding, and interests between fall and spring quarters. (5 = strong, 1 = weak; Fall n = 16, Spring n = 17)

in field research and natural history than other elements, yet they had high interests. Taken together, the positive is the students' enthusiasm for the course, despite being required, and the reality is they lack ecology concepts and skills coming in. This lack of background material reflects a challenge faced when utilizing SL in science courses. The only statistically significant differences between terms in the pre-course survey were in ecology interest (ANOVA, $p < 0.05$) and field research background ($p < 0.05$), with both higher in fall term. Overall, the pre-course survey suggests the two quarters began with similar student characteristics, enabling differences in post-course surveys to be based on course content potentially more than student tendencies.

Post-course Survey

Results from post-course surveys show differences in understanding and interests among the students in fall and spring quarters (Figure 2). In the majority of categories, spring quarter students indicated greater understanding and interest than fall quarter students. Students who experienced direct service learning by working with high school students on research projects had greater ecology understanding (ANOVA, $p = 0.059$), research interest ($p < 0.05$), field research understanding ($p = 0.054$), service project understanding ($p = 0.052$), service project interest ($p = 0.055$), and natural history understanding ($p < 0.05$). While by no means conclusive, this suggests that participation in direct SL may have enhanced the course experience for the spring students. To examine more closely changes in student perceptions, the difference between pre- and post-course values were calculated.

Results showing changes from pre- to post-course reinforce spring quarter students indicating higher understanding and interest, and illustrate categories where the change was greatest (Figure 3). Overall, the majority of categories demonstrate increases in understanding and interest, hopefully reflecting that the course helped the students learn and increase their enthusiasm for ecology.

Student responses suggest interest in ecology increased slightly, but understanding increased greatly both quarters,

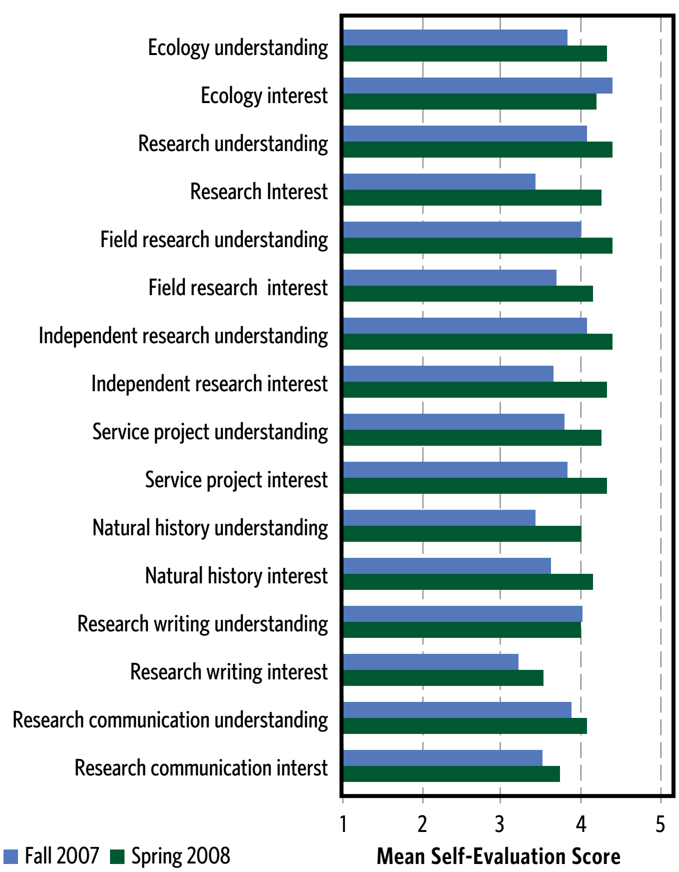


FIGURE 2. Differences emerge in post-course surveys of understanding and interests between fall and spring quarters. (5 = strong, 1 = weak; Fall n = 16, Spring n = 17)

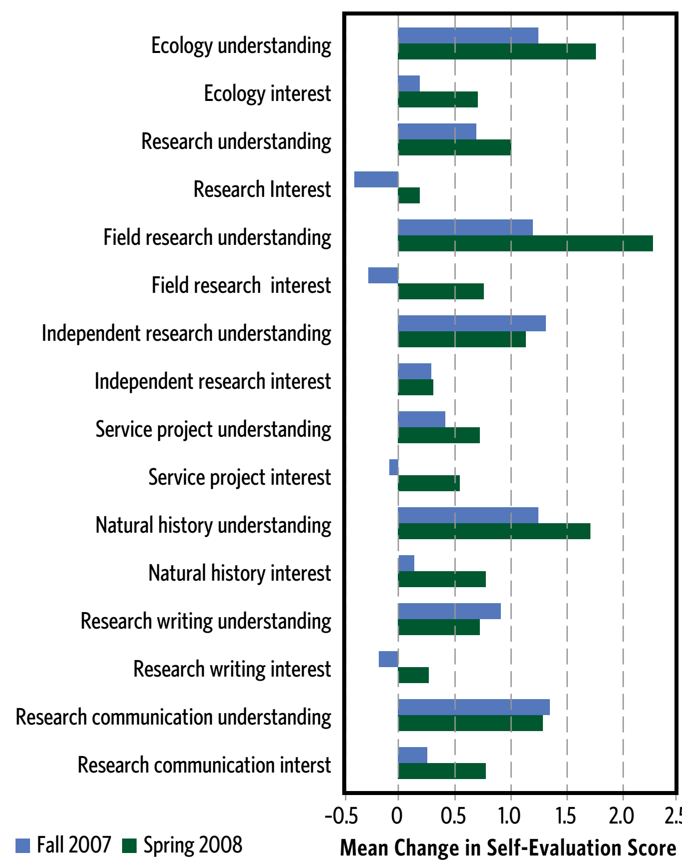


FIGURE 3. Differences in understanding and interest between pre- and post-course surveys. Overall, both courses increased understanding and interests. There are some differences in the magnitude of increases between Fall and Spring quarters. (Fall n = 16, Spring n = 17)

with an even greater increase in the spring (ANOVA, $p = 0.166$). While sparking interest is a goal of the course, generating greater understanding is more so, and the potential for direct SL to further increase that understanding is exciting.

Regarding research, understanding again increased more than interest in both quarters, but change in research interest was higher in spring ($p < 0.05$) potentially due to lower values in the pre-survey. The most substantial differences between quarters were in field research understanding ($p < 0.005$) and interest ($p < 0.05$), and there exists the possibility that the direct SL where the students had to guide the high school students through all the aspects of ecological methods may have strengthened that understanding.

Not surprisingly, service project understanding and interest had greater increases where students participated in direct compared to indirect SL (understanding: $p = 0.252$, interest: $p < 0.05$). The indirect model is certainly valuable, and in some ways logistically easier, but the direct model required greater investment by the students. That said, there were a number of occasions over the course of spring quarter where the students seemed to lack real investment in the high school activity. Due to the timing of the visits to Summit, there were a number of students who could not or did not make the effort to join us. While there was always a representative from each team, there was a distinct lack of continuity, and this was noted by the high school students and affected team dynamics. All ecology students did prioritize the all day field event, which was by far the most important element of the SL project, but future courses must identify ways to increase student investment and identify appropriate incentives or requirements.

The two categories where changes in understanding did not differ between quarters were research writing and communication. In fact, writing understanding increased more in the fall, and this may very well be due to the peer review process used in fall but not in spring. In official university evaluations, multiple students commented on the usefulness of the peer reviewing in the fall, as well. Peer reviewing was sacrificed during planning for spring due to lack of sufficient time for reviewing given other commitments to the Summit High project. This reflects the challenge of courses having zero-sum syllabi. Despite the laudable goals of both peer reviewing and SL, it is a challenge to fit both, and if the structure were altered something else would have to give. The lack of differences in communication may be related to writing, since fall students incorporated peer suggestions not just into their reports, but also their presentations. Though, the greater increase in communication interest by spring students may reflect their experiences having to communicate concepts guiding the high school students. By garnering feedback from the students and their achievements, the decisions on syllabi can be made more systematically.

Grades

Final grade distributions among students in fall and spring quarters were similar (Figure 4; Chi-square $p = 0.497$). The experience with direct SL and the absence of other elements did not appear to dramatically affect final course grades.

Mean assignment grades did appear to differ somewhat between fall and spring quarters (Figure 5; ANOVA $p < 0.001$). Related to comments above on the peer review process in fall quarter, the slightly higher grades on the peer-reviewed paper (Seward) should not be surprising. Higher grades on the Duwamish paper may be attributable to increased writing acumen due to the overall peer review process improving the second paper as well. The higher grades on the final in spring compared to fall are surprising ($p < 0.001$), but it is difficult to attribute the direct SL experience compared to other factors as a primary cause for better exam grades.

Feedback

The spring ecology students indicated they found the direct SL experience with the Summit High students to be overwhelmingly positive (Figure 6). From the feedback survey, students seemed to find the project enjoyable, well planned,

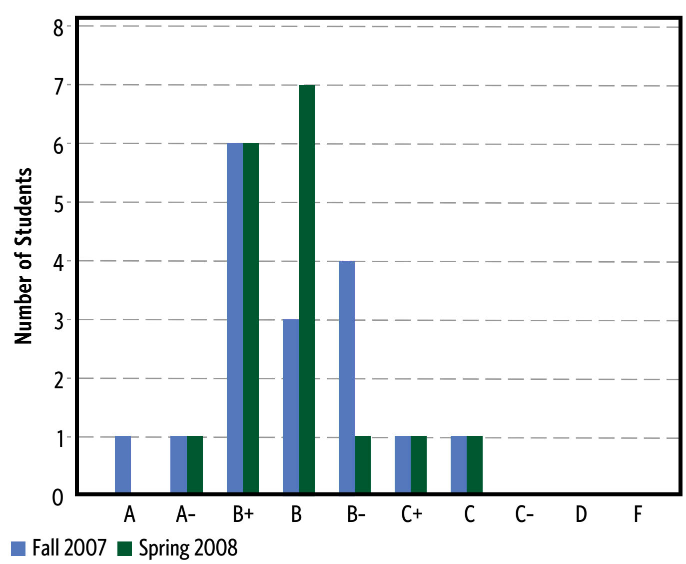


FIGURE 4. Similar grade distributions between fall and spring quarters (Chi-square p = 0.497; fall n = 16, spring n = 17).

educational, and rewarding to interact with the high school students.

Additional comments from ecology students focused on: the Summit students' enthusiasm, the worth of sharing and presenting the final data analysis, and gaining an appreciation for teaching. Suggestions for next time include: more variety in projects, adding laboratory work, increasing time for interactions among the students, and giving more suggestions for how to continue helping out in the community.

The feedback from the Summit students provided an opportunity to assess what they learned from the ecology students and the whole experience. The Summit students enjoyed having the opportunity to interact with college students, since these students at an alternative high school do not normally get to do so. Summit students mentioned the techniques and tools they learned to use, and a greater awareness of the condition of the river with implications for public health. Impressively, some Summit students' comments indicate their understanding of the connections among organisms and habitats, and the value of restoration efforts.

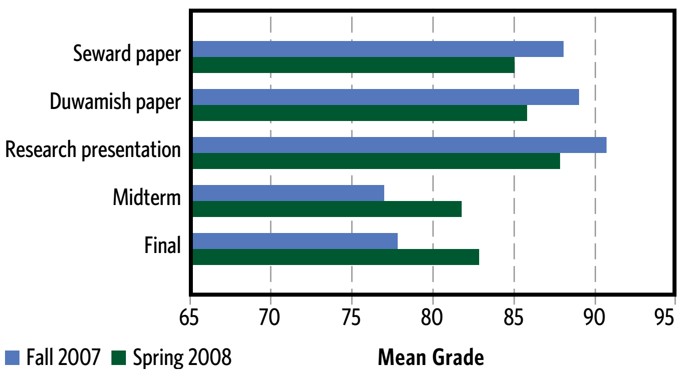


FIGURE 5. Grade differences between quarters on research papers, presentations, and exams (2-way ANOVA Course x Assignment p < 0.001; Fall n = 16, Spring n = 17)

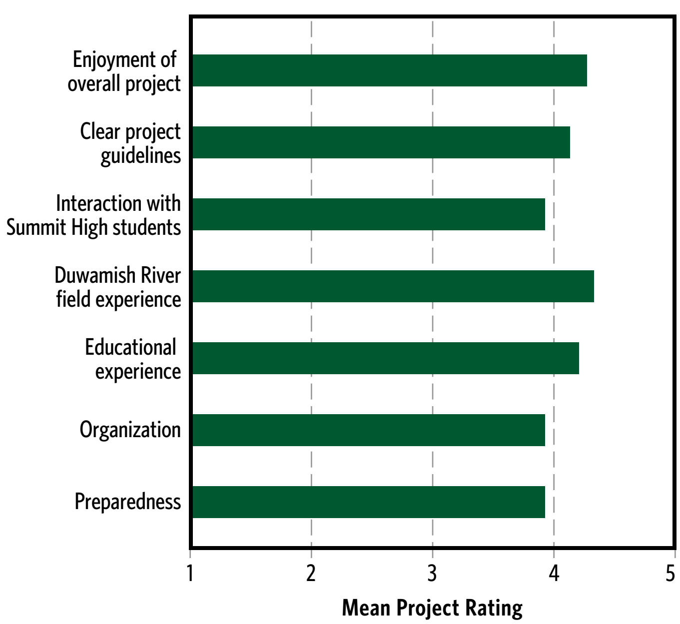


FIGURE 6. Feedback from students on direct SL component working with high school students. (5 = excellent, 1 = poor; n=14)

These comments were shared with the ecology students at the end of the course, and were an excellent reminder of the value of their efforts beyond learning the ecology for their grade. The feedback from the Summit students accentuated the positive experience from the SL project and provides the impetus to continually improve how the course incorporates SL. Specific insightful comments from the high school students include:

- "[O]pportunity to work with real college students on site, which is pretty rare."
- "I learned how to test for phosphorus, nitrate, turbidity, and plankton in the water. I also learned some new types and uses for plants."
- "That [the work] isn't that bad and it was fun and constructive. Also, that plankton can make a big difference in the life of fish."
- "Cleaning is good, and we need to be more careful [about] what we put in our rivers."
- "I don't really feel that I helped people so much as plants and animals. I suppose through data collecting we were helping both. People, to better help them understand what's going on at the site, which may help the environment."

Conclusions

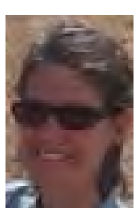
Prior to initiating this action research project, the challenges to incorporating SL into courses were clear, but the experience highlighted a few. The zero-sum aspect of courses was illustrated through the survey results and grades, and future iterations of the ecology course will strive to integrate peer reviewing along with direct SL effectively. The lack of student expertise was somewhat assuaged during conversations with community partners, as they emphasized the value of any data. Particularly memorable was the comment from Eliza Ghitis of People for Puget Sound. She pointed out that—instead of one partially trained volunteer walking the marsh twice a year—they would have about thirty students that they knew had taken ecology dedicating even more time, which was well worth the partnership. Student commitment is always a challenge with so many other items on their plates, but feedback from the Summit students heightened the need to adjust the SL design to enable greater continuity. The website and peer-reviewing will continue to be improved to increase the quality of reports and data, as well.

The rewards of SL are achieved through indirect involvement with community partners, but multiple aspects of this action research project indicate that direct experience enhanced those rewards all the more. From a course material perspective, the ecology students had to work to increase their understanding of concepts and techniques to be able to guide the Summit students and answer their plethora of questions. Explaining their research projects to high school students in terms they could comprehend also emphasized the value of generating information for an audience beyond the college classroom. By incorporating SL, both courses recognized greater relevance of the ecological concepts to the local community, but perhaps in the spring ecology students felt they had even more opportunity to interact with community members .

Overall, this action research project demonstrates not only that SL can be effectively incorporated into an ecology course, but also that the challenges of direct SL can generate rewards in increased student understanding, interests, and becoming effective educators themselves.

About the Authors

Lindsay Whitlow is currently assistant professor of biology at Seattle University in Seattle, WA. He earned his Ph.D. in ecology and evolutionary biology from the University of Michigan in 2002. His primary interests lie in collaborating with undergraduates on ecology research focused on the effects of urbanization, contamination, invasion, and restoration in aquatic and terrestrial ecosystems. He teaches both introductory and advanced biology courses, and has recently developed interdisciplinary service-learning courses with colleagues to investigate emerging contaminants in polluted urban waterways.



Sara Hoofnagle is currently a science teacher at Eckstein Middle School in Seattle, WA. She earned her undergraduate degree in natural resources at Cornell University in 1995. She went on to earn her masters in education at the University of Colorado, Denver in 2003. Her professional interests include finding novel methods for bringing outdoor education into her classroom and connecting students with different careers in science.

Appendix: Pre-Course Survey

Student Number: ______________________________

Major: ______________________________

Year in School: ❏ 1 ❏ 2 ❏ 3 ❏ 4 ❏ Other

This course fulfills:
❏ requirement for major
❏ requirement for minor
❏ elective general education requirement
❏ personal interest

❏ Strong (5) ❏ Moderate (3) ❏ Weak (1)

My background in ecology:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My understanding of ecology:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in ecology:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in biology:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in field research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in field research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in independent research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in independent research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in service projects:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in service projects:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in natural history:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in natural history:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in scientific writing:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in scientific writing:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My background in communicating research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1
My interest in communicating research:	❏ 5	❏ 4	❏ 3	❏ 2	❏ 1

In the space on the back, please provide any additional information you'd like to share about your interests, understanding or background relevant to this course.

References

Brubaker, D.C., and J.H. Ostroff, eds. 2000. *Life, Learning, and Community: Concepts and Models for Service-Learning.* Washington, D.C.: American Association for Higher Education.

Colorado State University (CSU). 2010. "Types of Service-Learning Activities." tilt.colostate.edu/sl/faculty/types.cfm (accessed December 30, 2010).

Coomey, S.M., and F.L. Wilcenski. 2005. *Does the Service Matter? Comparative Benefits of Direct and Indirect Service Learning Experiences.* University of Massachusetts-Boston, Boston, MA.

Deegan, M.M., G. Gambino, and C.P. Borick. 2009. "Connecting Students to Their Community: A Public Research Model of Service." *Council on Undergraduate Research Quarterly* 29: 18–22.

deKoven, A., and D. Trumbull. 2002. "Science Graduates Doing Science Outreach: Participation Effects and Perceived Barriers to Participation." *Electronic Journal of Science Education* 7(1). ejse.southwestern.edu/article/view/7696/5463 (accessed December 30, 2010).

Draper, A.J. 2004. "Integrating Project- Based Service-Learning into an Advanced Environmental Chemistry Course." *Journal of Chemical Education* 2: 221–224.

Furco, A. 2001. "Advancing Service Learning at Research Universities," *New Directions for Higher Education* 114: 67–78.

Haines, S. 2003. "Incorporating Service Learning Components into Biology Education." *Journal of College Science Teaching* 32: 440–442.

Kaye, C.B. 2004. *The Complete Guide to Service Learning: Proven, Practical Ways to Engage Students in Civic Responsibility, Academic Curriculum, and Social Action.* Free Spirit Publishing, Minneapolis, MN.

Leege, L., and M. Cawthorn. 2008. "Environmental Service Learning: Relevant, Rewarding, and Responsible." *Journal of College Science Teaching* 37: 32–36.

National Science Teachers Association (NSTA). 2009. "Blending Science and Service-Learning." *NSTA Reports* 21: 1–2.

Ohio State University (OSU). 2010. "Elements of a Service-Learning Course. Service-Learning Initiative The Ohio State University." service-learning.osu.edu/docs/elements_SLCourse.pdf (accessed December 30, 2010).

Reardon, K. "Participatory Action Research as Service Learning." In *Academic Service Learning: A Pedagogy of Action and Reflection,* R.A. Rhoads and J.P.F. Howard eds., New Directions for Teaching and Learning, No. 73. San Francisco: Jossey-Bass, 1998.

Sherman, A., and L. MacDonald. 2009. "Service Learning Experiences in University Science Degree Courses." *Innovations in Higher Education* 34: 235–244.