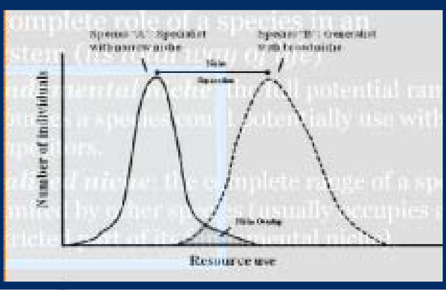

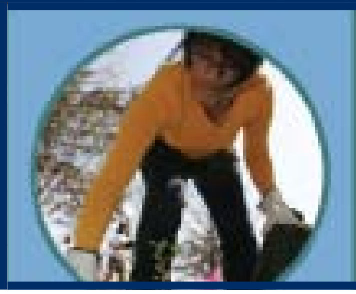


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Contents

From the Editors

We are pleased to announce the Summer 2012 issue of *Science Education and Civic Engagement: An International Journal.*

Vance High and James Rye at West Virginia University have contributed a research article titled "Engaging within Time Limits: An Integrated Approach for Elementary Science." This article describes a creative approach to teaching inquiry-based environmental science in elementary school by linking it to children's literature. Using this linkage strategy, the authors measured positive changes in the attitudes of pre-service elementary school teachers towards teaching science.

The four project reports in this issue present a diversity of topics, including quantitative reasoning, bacteriology, and ecology. A team of educators — Abour Cherif (DeVry University), Linda Michel (DeVry University Online), Nancy Marthakis (Purdue University North Central) and Farahnaz Movahedzadeh (Harold Washington College)— use interesting discoveries about our body's bacterial neighbors to promote active learning in biology classes. Marina Dedlovskaya and Patricia Sokolski, both from LaGuardia Community College, explain the benefits of integrating a reflective component into a quantitative reasoning course, which included civic topics such as recycling and calculating a personal ecological footprint. Mark Fink, M. Leigh Lunsford, Suzanne M. Donnelly, Melissa C. Rhoten, Kelsey N. Scheitlin, and Alix D. Dowling Fink, all at Longwood University in Virginia, use the Chesapeake Bay, North America's largest estuary system, as a meaningful location for active learning and civic engagement. Finally, David Green at Florida Gulf Coast University shows how integrating emerging technologies into two non-majors ecology courses can stimulate students' creativity while providing valuable interactive resources for local communities.

We wish to express our gratitude to all the authors who have shared their interesting research and educational projects with the readers of this journal.

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

PROJECT REPORT

How Well Do You Know Your Closest Bacterial Neighbors?

Promoting Active Learning in Biology Classes

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Abstract

The human body is teeming with microbial life in that bacteria even outnumber the total quantity of human cells. Some of these microbes are non-pathogenic, some cause diseases, some are beneficial, and others have no apparent function. We provide explicit learning activities, reading and homework assignments, and assessment techniques that help instructors to engage their students in exploring and learning about the bacteria that co-inhabit or colonize the human body. Throughout this learning activity, students engage in active learning to explore, research, and learn about both indigenous and foreign bacteria. By engaging today's students in realistic learning activities such as these, we create an environment that promotes active learning through involvement in critical thinking, collaborative learning, problem solving, and knowledge creation within the context of content-based knowledge—skills and habits that are needed in the next generation of physicians, researchers, communicators, civic leaders, and public policy makers. This topic is of civic important because humans live with disease-causing microorganisms all around them and infectious diseases are one of the major causes of death in the world. Students need this knowledge base as they attempt to deal effectively with issues such as nutrition, health, safety, and wellness and public health, for their own and successive generations.

Introduction

A number of organizations including the Association for Prevention Teaching and Research (APTR), the Council of College of Arts and Sciences (CCAS), the Association of Schools of Public Health, and the Association of American Colleges and Universities have affirmed that "an understanding of [individual and] public health is a critical component of good citizenship and a prerequisite for taking responsibility for building healthy societies" (AAC&U 2011). It is important because humans live with disease-causing microorganisms all around them. While some microorganisms, such as bacteria, live on or in the human body without causing diseases and some are beneficial, a number of them are not. Indeed, infectious diseases are one of the major causes of death in the world (Neighbors and Tannehill-Jones 2010). Understanding how microorganisms interact with the human body is important knowledge affecting both individual and public health. Students need this knowledge to make informed decisions about nutrition, health, safety, wellness and public health for their own and successive generations. In this article we describe specific active-learning strategies that help students understand the connections between individual and public health and a working understanding of microorganisms, given them the tools they need to effectively engage in informed civic action.

Civic engagement has been defined as informed individual and collective actions designed to both identify and actively engage in issues of public concern and thus contribute productively to civic and public life. With these instructional activities and teaching strategies, we aim to help students as citizens, to:

- Identify, learn, and talk about vital issues, such as public health and microorganisms, in their lives, communities and organizations,
- Develop understanding, insights and solutions for those issues, and
- Inform others in the community to help insure that public policy supports the well-being of individuals, communities, and societies.

To learn, students need to do more than just receive information by listening to lectures, memorizing facts, and taking quizzes or exams. Instead, students must actively be involved in such higher-order thinking tasks as analysis, synthesis, and evaluation through reading, writing, discussions, and problem solving (Bonwell and Eison 1991, Niemi 2002, Meyers and Jones 1993). Within this context, "active learning would require the instructors to design their instructional activities to engage students in doing things and thinking about what they are doing" (Bonwell and Eison 1991, p. 1). It also would require student to be accountable for their learning, make something out of what they learn, and apply what they have learned in different situations. In other words, student need to show accumulated evidence of content knowledge, academic skills, comprehension, and must meaningfully apply learned knowledge and skills.

Background Information

We frequently hear news and information about bacteria from hospitals, universities, research institutions, and related organizations. There is a lot of interest in bacteria because the human body is teeming with microbes to the extent that their numbers exceed the total quantity of human cells. Microbes have been around for billions of years, living in and on the human body and everything around it. In fact, they outnumber our 100 quadrillion human cells by a factor of ten.

Bacteria are highly prolific, reproducing in a matter of minutes, and cover the human body as a whole, including its individual organs, with a composite of microbial species. Bacteria inhabit many areas of our bodies including our skin, digestive tract, nasal passages, hair and eyelashes, eyes, and teeth (Cf., Bryson 2003, Neighbors and Tannehill-Johnes 2010, Finlay 2010). For example, it has been estimated that human skin "hosts more than a million microbes per square centimeter"; one milliliter of saliva "contains about 1,000,000,000 bacteria"; and the digestive system alone is host to more than a hundred trillion microbes of at least four hundred types (Tenneson 2011, Kirshenbaum, 2011). Some deal "with sugars, some with starches, and some attack other bacteria, and some others have yet no detectable function at all" (Bryson, 2003, p. 302-303).

To give an example of the quantity of bacteria found in the human gut, a patient with *Clostridium difficile* diarrhea could "excrete 10,000 to 10 million organisms per gram of feces; a gram corresponds to just a quarter-teaspoon" (Dunavan, 2010, p. 26). In addition to the bacteria that are crucial to the digestive process, the human gut also contains bacteria-invading viruses. The role these viruses play is largely unknown, but they most likely have a mutualistic relationship in aiding metabolism and contributing to the stability of the gut's microbial community and complex ecosystem (McGowan 2011). Scientists have identified the "complex ecosystem of bacteria throughout a person's body as the microbiome" (Lee, 2010, p. 242). The term microbiome, which was first coined by Joshua Lederberg, is defined as "the totality of microbes, their genetic elements (genomes), and environmental interactions in a defined environment" (Wikipedia encyclopedia, 2011). These bacteria and other microbes including fungi and viruses, live all over our bodies. Microbes are found on our skin, our nose and respiratory tract, our urogenital tract, our mouth, and our digestive tract. These microbes can impact our health in both positive and negative ways. For example, gut bacteria aid in digestion and provide us with nutrients but at the same time, they have been linked to obesity and bowel diseases (Yong, 2012). A person's microbiome can be influenced by a number of factors including what they touch, eat, and breathe as well as how they were born, whether vaginally or by Cesarean section (Lee 2010).

So if you are ever feeling lonely, just remember that you are never truly alone. You are always in the company of your personal microbiome of bacteria. Indeed, in addition to our blood type, DNA, and fingerprints, forensic investigators think that the "ecosystems of bacteria that live on our skin and get left behind on everything we touch are unique and descriptive, meaning that they could provide a new way to establish identity" (Talkington 2010, p. 19). Furthermore, in addition to living on humans and other organisms, bacteria are ubiquitous in every imaginable habitat on the planet earth, including hot springs, salt lakes, and streams polluted with acidic mine runoff. We are in constant contact on a daily bases with bacteria from the world in which we live.

We need to remember however, while m*ost* bacteria are harmless and necessary for supporting humans and all life on Earth, a minority are not. They form a parasitic association with living organisms, causing various infections and diseases.

> *Of all the tens of thousands of known bacterial species, only about 100 are renegades that break the rules of peaceful coexistence and make us sick. Collectively, those pathogens can cause a lot of trouble. Infectious diseases are the second leading cause of death worldwide, and bacteria are well represented among the killers. Tuberculosis alone takes nearly two million lives every year, and* Yersinia pestis, *infamous for causing bubonic plague, killed approximately one third of Europe's population in the 14th century. Investigators have made considerable progress over the past 100 years in taming some species with antibiotics, but the harmful bacteria have also found ways [through the evolutionary processes] to resist many of those drugs. It is an arms race that humans have been losing of late, in part because we have not understood our enemy [meaning microbial* neighbors] *very well." (Finlay 2010, p. 57)*

This is very important because a number of pathogens have "evolved from harmless microbes by acquiring genes that confer new [pathogenic] properties" (Finlay 2010, p. 62). For example, a common microbe living on human skin, "*Staphylococcus aureus*, is usually harmless but can lead to serious infections" (Tennesen 2011, p. 37). Furthermore, some non-pathogenic bacteria that are native to the human body can become pathogenic if the physiological and or anatomical status of the body is changed or if they are introduced into a different area of the body. For example, *E. coli* is a harmless resident of the colon but it can cause meningitis if it gets into the cerebrospinal fluid. *Clostridium difficile* is also found in the colon but it can overgrow and cause pseudomembranous colitis after antibiotic use. The paramecium *Pneumocystis jiroveci* is often found in the lungs but it can cause serious pneumonia in AIDS patients and in patients who have had chemotherapy treatments.

Like other organisms, the human body is equipped with an immune system that is designed to resist, fight, and eliminate an infinite number of changes and attacks brought about by foreign agents in its environment, including microbes (Harry J. Johnson, cited in Wait 2001, p. 235). Bacterial pathogens, however, are equipped with virulence factors designed to elude our defenses so they can survive and reproduce. But bacteria should not be blamed for performing activities that they were created to do and which are programmed in their genetic code. When they make us ill and cause us to sneeze, cough, vomit, or have diarrhea, they are simply facilitating their survival by spreading through the environment and infecting more people (Finlay 2010, Cherif, et. al 2009, Bryson 2003, Konneman 2002). And among those harmful bacteria, some of them still provide essential service to the human body. For example, *Propionibacterium acnes* has been associated with acne. But because *P. acnes* thrives on the oily, waxy remains of dead cells, it breaks down oil into a natural moisturizer for human skin (Tennesen 2011).

Bacteria do not live in isolation. Whether they are harmful or beneficial, or whether they live in the human body or in the external environment, most groups of bacteria form microbiomes of diverse ecosystems and behave as multicellular organisms. (Tennesen, 2011; Williams, 2010), They have developed very sophisticated systems of communication, using a rich chemical lexicon, and they send and receive signals to and from other bacteria. By "talking" to each other, they act in unison to perform fascinating functions, such as bioluminescence, sporulation, DNA transfer, biofilm formation, population density estimates, and pathogenesis. Scientists have used their knowledge of intercellular communication amongst microbes to further their research on topics pertaining to bacterial physiology, ecology and bacterial disease (Bassler, 2009; Winans & Bassler, 2008).

Bacteria such as *Staphylococcus epidermidis,* which live on our skin, work together to prevent deadly *Staphylococcus* *aurous* strains from taking hold (Tennesen, 2011). Other bacteria work together to protect each other when faced with doses of antibiotics. For example James J. Collins and his research team have found that:

> *The few truly antibiotic-resistant bacteria emit a compound called indole that signals the rest of bacteria to ramp up their defenses. When the nonresistant pathogens sense indole, they turn on a pump that expels antibiotics from the cell, and they turn on chemical pathways that protect them from the toxic molecules antibiotics normally induce inside bacteria.* (Williams, 2010, p. 42)

Others turn toxic only when their neighbors are in danger and need help. Still others are opportunistic pathogens that cause disease mainly in people with a compromised immune system as a result of change in their body's physiology or who are suffering from a chronic condition such as cystic fibrosis.

A better understanding of these bacterial strategies of collaboration and communication may help us create inhibitors to disrupt them as well as give us strategies for co-existing with our closest bacterial neighbors in a harmonious environment. Then we will be able to utilize their unique survival mechanisms to improve our own lives. In addition, it will also help us figure out how to support the survival of our beneficial bacterial neighbors, and even help our immune systems to better fight the pathogens. This could reduce the number of patients worldwide with compromised immune systems, which has been rising in the last twenty-five years (Hayden, Carrol, Tang, and Wolk, 2008). It is possible that some of the trillions of microbes that live in the human body will teach us how to fight disease without antibiotics and thus achieve a new level of individual and public health.

Microorganisms that typically colonize the human body (host) without normally causing disease are known as the body's normal microbiota, normal flora, or the indigenous microbiota. There are two types of normal microbiota, resident and transient. Resident microbiota are part of the body's normal flora and do not cause disease under normal conditions. Most of the resident microbiota are commensal, found on the skin and on the mucous membranes of the digestive tract, upper respiratory tract, distal portion of the urethra, and vagina without causing harm (Bauman 2012; Tortora, Funke, & Case 2012; Lim, 2003). Transient microbiota remain in the human body (host) only for a short time (ex. a few hours, days, or months) before disappearing and without causing a disease. While the members of both resident and transient microbiota are found in the same locations, the transient microbiota cannot persist because of "competition from other microorganisms, elimination by the body's defense cells, or chemical and physical changes in the body that dislodge them" (Bauman 2012, p. 412).

Indigenous opportunistic bacteria are non-pathogenic bacteria that are native to the human body but can become pathogenic if the physiological and/or anatomical status of the body is changed. They can also cause infection if they are introduced into a different area of the body. While the human body teams with microbial life forms, many parts of the human body are sites free of any microbes. This type of site is known as an *axenic* environment. For example a mother's uterus is an axenic environment and this is one of the reasons that babies develop in their mothers' wombs without normal microbiota. But after all, to the bacteria themselves, the human beings probably seem like just a small part of their world, a world on which they have existed for approximately 4 billion years (Koneman, 2002; Knoll, 2003; Bryson, 2003; Flannery, 2008). One might say, as Bryson (2003) did, we are but guests in their universe Thus, the best we can do to appreciate them is to learn not only how to co-exist with them but also how to benefit from them to make our life better for us and the world around us.

Learning Activity

In this learning activity, students work in groups of 3-4 to research various types of bacteria that are directly or indirectly associated with the human body. Each group selects at least one from each of the following categories:

1. Indigenous bacterium normally found on humans – e.g., on skin, in colon, gut, etc.
2. Foreign pathogenic bacterium – a bacterium that is not native to the human body and that causes a disease to humans.

Once the members of the groups have finished their research, they prepare a written report and an oral presentation to be given in class. To accomplish this goal, students work together to research, study, and collect information about their selected bacteria. By actively engaging in this activity, students learn and reinforce their understanding of the roles that pathogenic and non-pathogenic bacteria play in the existence and survival of humans and the world in which they live. But most of all, we aim to invoke an interest in learning and stimulate further exploration of these amazing microbes by the students' involvement. In turn, we hope to excite them about issues that may present themselves in their future, and give them supportive insight into solutions that could contribute to achieving desirable individual and public health.

Procedure

1. Divide the class into groups of 3-4 students, and inform each group member to work together to:

   a. Conduct research about bacteria that normally live on or in the human body as well as foreign pathogens which are not native to the human body. See table 1.

   b. Select one bacterial species from each category and then prepare a written paper, handout, and oral presentation on each one. The presentation must convey information and integrate the use of technology such as PowerPoint, animations, interactive activities, etc.

2. Ask each group to prepare two relevant critical thinking questions to submit for a class quiz and potential exam poll questions.
3. Give the students 2 to 3 weeks (time can be shortened or lengthened) to prepare their written paper, hand-out, and presentation.
4. At every class meeting, make sure that students are working on their assignments. For example, give 10–15 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 toward the written paper, poster, additional aids, and the oral presentation.
5. Students are advised to start their research by reading at least five of the following articles which can easily be found in the college libraries, nearby public libraries, and bookstores: Ananthaswamy (2010), Bassler (2009), Dunavan (2010), Finlay (2010), Hughes (2011), Koening (2010), Koneman (2002), Marsa (2010), Tennesen (2011), and Walsh and Fischbach (2009)
6. Remind the students that the objectives in this learning activity are to help them develop:

   a. Breadth of knowledge and depth of understanding of concepts and vocabulary of the microbial world and the roles of bacteria in human life and in our contemporary technological society.

   b. An understanding of the social, economic and environmental implications and limitations of science, technology, and genetic engineering.

   c. An awareness of their own attitudes, feelings and values about microbes and how they differ from others.

   d. An awareness of the importance of microbial diversity in environmental protection/stewardship, economy and sustainability.

   e. Team work and communication skills.

   f. Critical thinking and problem-solving skills.

Discussion Questions:

1. Where, on or in the human body, are:

   a. the most of the indigenous bacteria found?

   b. the least, or no indigenous bacteria found?

   c. the sites free of any microbes (axenic environment)?

2. Humans constantly come into contact with external agents including disease-causing microorganisms that could be harmful if they enter the body. Through which parts of the human body do most foreign bacteria enter the human body and use as a host for food and/or reproduction?
3. What is an antibiotic? How does an antibiotic work? Who discovered the first antibiotic? If you have to write a letter to this scientist, what would you write and why?
4. What is an antibody? How does an antibody work? Compare and contrast between antibiotic and antibody.

TABLE 1. EACH GROUP SELECTS ONE OF EACH OF THE FIVE CATEGORIES OF BACTERIA TO RESEARCH AND PRESENT

Type of Bacteria	Example	Its Nature	Found	Its relationship with Human body
Indigenous lives inside the human body.				
Indigenous lives on the human body.				
Indigenous opportunistic* lives in or on the human body				
Foreign pathogenic infects inside the human body				
Foreign pathogenic infects outside the human body				

* Indigenous opportunistic bacteria are non-pathogenic bacteria that are native to the human body but can become pathogenic if the physiological and or anatomical status of the body is changed. They can also cause infection if they are introduced into a different area of the body.

5. How do bacteria evolve to become antibiotic resistant?
6. Under what other circumstances might some bacteria develop drug resistance without being exposed to any antibiotics?
7. It has been argued that to fight bacteria, we need better information about how they acquire their disturbing power of attacking us. From your perspective, how might we be able to change those pathogenic bacteria to harmless and or beneficial bacteria?
8. Under what possible circumstances or conditions might a given indigenous harmless or beneficial bacteria become pathogenic?
9. Bacterial infections may be treated with antibiotics, which are classified as bacteriocidal or bacteriostatic. Compare and contrast between the two classes of antibiotics.
10. Conduct research to explain:

    a. Why nitrogen and phosphorus are added to beaches following an oil spill?

    b. Why do scientists insert the so-called suicide genes into genetically engineered cells along with the gene of interest?

    c. Why do you think it is very hard to consider a given bacteria entering the human body as a foreign non-pathogenic bacteria?

11. Which characteristics do bacteria possess that qualifies them as suitable organisms to be genetically engineered?
12. What types of biological facts have made genetic engineering a possible reality and a fact of biological life?
13. If you have to write a letter of appreciation and provide an update about the human understanding of microorganisms to the following scientists, what would you write and why? Anton van Leeuwenhoek (1632-1723) who opened the door to the new world of microorganisms with his early development of microscopies and discoveries of microorganisms; Louis Pasteur (1822-1895) who disapproved the theory of spontaneous generation, developed vaccines for anthrax and rabies, and developed a process of pasteurization; and Robert Koch (1843-1910) who in 1876 established a series of criteria necessary for association of specific microorganisms with specific diseases, which today is known as Koch's Postulates.

Homework Assignment and Additional Related Activities:

When all the groups complete their presentations, give the homework assignments and additional related activities in appendix 1 to students to work on and complete individually or in groups. They can be used as homework assignments or research topics.

Assessment:

Using both formative and summative assessment, students are assessed based on:

1. How well they:
   a. Conduct their research.
   b. Present their research and make it personal and relevant.
   c. Show the significance of the different types of bacteria selected for their presentation.
   d. Respond to the questions asked by their classmates after their presentations.
   e. Answer the imaginative question of "What would the different types of bacteria say to each other in their encounter on or in the human body"?
2. How many relevant critical thinking questions they submit for quizzes and potential exam polls.
3. How well they completed the homework assignment and answered the related questions.
4. The academic quality and integrity of the written paper, oral presentation, poster illustration, and/or any additional aids used by the students to convey their message.
5. Clear evidence that the members of a given group conducted research beyond the suggested articles assigned by the instructor for all the students to read.
6. 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 presentation and following discussion.
7. The type and quality of questions asked and the quality of the answers the group provided to questions directed at them. Teachers and instructors can refer to Cherif et al. (2009, 2011) 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.

The instructor of the class must reinforce the principles of DNA structure and replication, genetic mutations, genetic engineering, microbiomes, indigenous and foreign microbes, infectious diseases, antibody and antibiotic, and resistance to drugs and insecticides. Other topics that can be discussed include the role of microbes in biological diversity, environmental sustainability, economic prosperity, and the importance of microbes in public health, both beneficial and disease-causing. Also, additional relevant topics to address may include when and how harmless bacteria acquire genes and evolve to be pathogens and vice versa.

Conclusion

Today, human societies are faced with many complex challenges, including medical, environmental, agricultural, and economic to name a few. These challenges require revolutionary approaches to understanding the characteristics and the functions of microbial communities, including how they support all life on Earth and how bacteria inhabit living bodies and ensure their healthy survival. In this learning activity we aim to increase students' awareness of our paradoxical relationship with the microbial world, with the main emphasis on bacteria. The goal is to motivate students' curiosity and earnestly explore and understand the unseen microbial world within the context of the human body. After all, microorganisms, which may always invade our tissues, may also be a means for providing us with healthy bodies and supporting environmental well being.

Microbes are everywhere; they live in our bodies, and in everything that surrounds us. We cannot live without them. Therefore, understanding microbial communities is necessary to enhance our understanding of ourselves and how we can solve many of the challenges that are facing us today, such as public health, global environmental changes, the use of biologically-based energy resources, restoring healthy ecosystems, and producing food for feeding the rapidly increasing world population, to name a few.

By engaging today's students in realistic learning activities such as these, we create learning environments that promote active learning, critical thinking, collaborative learning, and knowledge creation—habits that are urgently needed in the next generation of physicians, researchers, communicators and public policy makers. They will need this knowledge base as they attempt to deal effectively with issues such as nutrition, health, safety, and wellness for their own and successive generations.

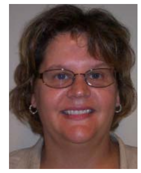
Answers to Questions Raised in the Learning Activities:

A complete and detailed list of answers to all the questions raised in the learning activities in this paper are available electronically based on individual request by e-mailing anyone of the authors.

About the Authors

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, coauthored 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 an assistant professor in the Department of Biological Sciences at Harold Washington College in Chicago, Illinois. She 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.



Nancy Marthakis has demonstrated a commitment to students that extends beyond the formal classroom. She is an Osteopathic physician who has a passion to facilitate learning as an Associate Professor at Purdue University North Central's Department of Biological Sciences; by maintaining and enhancing education through strategies that integrate over 15 years of health care experience with student centered learning. Her background as a Microbiologist and an Internist has provided her with an extensive professional history that encompasses all aspects of medicine. She has taught a wide range of higher education courses including Medical Ethics, Microbiology, Human Anatomy and Physiology, Immunobiology and Clinical Mycology. She is an Indiana Campus Compact 2010-2012 Senior Faculty Fellow, and is an active member of the Bioethics Committee at Saint Catherine Hospital in East Chicago, Indiana. She is also the chairman of the Advisory Board for the Northwest Indiana Area Health Education Committee, where she has mentored many students entering the field of medicine.

Linda Michel (lmichel@devry.edu) is a visiting professor at DeVry University Online. 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 chemistry and microbiology courses online for a number of years.

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Appendix 1

Additional Related Learning Activities

We frequently hear news and information about bacteria from hospitals, universities, research institutions, and related organizations. The following are additional homework assignments and related activities designed as startup learning activities to motivate students to explore and discover more about the bacterial world. Instructors can select those they find useful to integrate in their instructional time or to assign as individual or group projects for their students.

Activity: Bad Guys, Here I Come

Forensic scientists are very excited about the potential of new tools that might help them catch criminals more effectively. In addition to fingerprints and DNA, forensic scientists, lawyers, and law enforcement personnel have new tools to use, including pollen and some types of bacteria. Forensic investigators think that the "ecosystems of bacteria that live on our skin and get left behind on everything we touch are unique and descriptive, meaning that they could provide a new way to establish identity" (Talkington 2010, p. 19). Conduct internet research to find out how the ecosystems of bacteria could be used as an additional tool to help solve forensic problems and catch criminals.

Activity: The Human Body and its Bacterial Cohabitants

The human body is made up of trillions of cells. Additionally, it houses about 10 times that number of bacterial cells. Conduct research to identify at least five locations on the human body and their bacterial cohabitants. Then draw a structural map of the human body and indicate the location of those bacterial cohabitants that you identified. Draw the shape of these bacteria and identify their characteristics.

THE HUMAN BODY AND ITS BACTERIAL COHABITANTS

	Body Part	Bacterial Cohabitants	Bacterial Shape	Bacterial Characteristics
1				
2				
3				
4				
5				

Activity: Quorum Sensing

The phenomenon by which bacteria sense and respond to changes in microbial density in the vicinity by utilizing signal and receptor molecules is known as bacterial quorum sensing (Lim 2003; Bassler 2009; Bauman 2012). As a result, bacteria are able to "coordinate their activities and respond to changes in environmental conditions such as adaptation to nutrient availability and avoidance of toxic compounds or host immune responses" (Lim, 2003, p. 482). The main goal of quorum sensing research is to come up with inhibitors that could be used to alter the ability of bacteria to cause diseases. Researchers do this by identifying how bacteria communicate with each other and then interfere with their communication so they don't send and receive the messages or so they receive different messages and change their natural (innate) behavior.

In the bacterial world, there are two approaches of how pathogens cause illness after they find their way into a human body: either wait for help like *E-coli* or attack immediately like *Vibrio cholera.*

> *When E. coli finds its way into a human body, it doesn't start attacking immediately. It waits until it has a quorum, and then pow! Virulence factors turn on, and the human gets sick. In the case of E. coli, the bacteria start to produce a toxin that wreaks havoc. The idea is to trick the E. coli into thinking that only a few other E. coli are around. Then no virulence factors turn on, so there's no toxin, and no grave illness.* (Staton, 2010, p. 70)

On the other hand, *Vibrio cholera* works in the opposite manner of *E. coli* and most other bacterial signals. This bacterium "doesn't wait until it's swimming in a critical mass of fellow bacteria to turn on virulence. It's virulent from the get-go; attacks immediately" (Staton, 2010, p. 70). The research scientists who work with quorum sensing are trying to trace the early stage signals of those germs that get humans seriously sick such as *V. cholera*. When they figure this out, then they can develop a strategy to treat and prevent the illness. This could be as simple as an amino acid or a sugar without the need for using complex and expensive drugs (Staton, 2010).

Conduct internet research to find out:

1. What is the difference between bacterial inter-species and intra-species communication?
2. How does quorum sensing contribute to a microbe's pathogenicity and virulence?
3. What are anti-quorum sensing molecules and why do some scientists refer to them as the next generation of antibiotics?
4. Is quorum sensing a characteristic associated only with pathogenic bacteria or pathogenic and non-pathogenic bacteria? Explain.

Activity: Bacteria Working Together

New studies on antibiotic resistance have shown that some types of bacteria have developed a very sophisticated strategy of collaboration that is essential for their species' survival. For example, *"E. coli* are more resistant to antibiotics as a group than as individual cells" (Williams, 2010, p. 42). Researchers from HHMI have found that "when faced with an oncoming dose of antibiotic, bacteria work together in a neighborly way. Microbes that are resistant to the drug protect their weaker kin in the colony" (Williams, 2010, p. 42). Under the wing and watchfulness of the stronger bacteria, this approach might help the weaker bacteria to slowly develop effective resistance over time, according to James J. Collins, an HHMI investigator at Boston University.

> *The usual thinking about resistance is that a mutation arises in one bacterium, and then that bacterium has a survival advantage and thrives, growing and dividing, while the others die off. But the team found that the bacterial population as a whole showed far more antibiotic resistance than did small sample of bacteria. And only a few bacteria had resistance-causing genetic mutations. The scientists found that the few truly antibiotic-resistance bacteria emit a compound called indole that signals the rest of the bacteria to ramp up their defenses. When the nonresistant pathogens sense indole, they turn on a pump that expels antibiotic from the cell, and they turn on chemical pathways that protect them from the toxic molecules antibiotics normally induce inside bacteria. Bacteria, although they are unicellular organisms, can behave as a multicellular organism from population standpoint.* (Cited in Williams, 2010, p. 42).

Conduct internet research to find out:

1. What is the difference between bacteriocidal and bacteriostatic antibiotics?
2. Why are multidrug resistant (MDR) strains of bacteria becoming more prevalent?
3. How do you treat MDR tuberculosis?

Activity: Planned Eradication of Bacterial Species to Prevent Diseases (Adapted from Cherif, et al, 2011).

Given the fact that species become extinct "all the time" and some types of bacteria cause serious disease, planned extinction doesn't seem to be a bad idea. After all,

> *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 encyclopedia, 2010b)

In her article, "A Bug's Death", Olivia Judson (2003) 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 "specicide" idea is a simple and straight forward 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 20 generations..* (Judson 2003)

While Judson (2003) was talking specifically about malaria which is spread by *Anopheles* mosquitoes and dengue fever, yellow fever, and elephantiasis which are spread by *Aedes* mosquitoes and not bacteria, it is not easy to predict the possible risks and consequences of planned extinction, especially for living forms such as bacteria. Conduct internet research to find out:

1. Why planned eradication of a given bacterial species might not be an easy task or might not work in comparison to other life forms?
2. If planned extinction of a given bacteria is possible, what is the possible ecological collapse and genetic escape for planned extinction of bacteria that cause deadly illness to humans?
3. Do you agree with the idea of planned extinction of a species to prevent serious diseases?
4. If you were to write a letter to Olivia Judson what would you write and why?
5. Compare and contrast genetic modification (engineering) as a tool of creation and as a tool of extinction.
6. 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 5 would you select? Explain.

Activity: A Bio-based Computer

The new advances in genetic engineering and synthetic biology have created the potential for biology-based, instead of silicon-based, computers that one day might solve complex biological and mathematical problems. According to Karmella Haynes, a researcher at Davidson College and lead study author, "The computing potential of DNA far exceeds that of any other material... If we figure out how to increase that capacity in a practical manner we will have much more computing power" (Cited in Bland 2008, p. 3).

> *A traditional, silica-based computer would run through every single possible solution to the problem, one at a time. In a biology-based computer, each bacterium becomes a single computer that runs a different part of the problem simultaneously. Since a million bacteria-based computers can fit into a single drop of water, all of them working together could speed up the calculations dramatically.* (Bland 2008, pp. 8-9)

This type of computer has the potential to allow researchers to conduct a wide variety of biological computing such as "telling researchers how many times they have encountered a certain chemical" (Bland 2008, p. 16).

1. Conduct internet research to find out:
   a. How biology-based computers work.
   b. What type of problems might biology-based computers face that reduce their efficiencies?
2. In 1937, the theoretical physicist John Vincent Atanasoff, who was a professor at Iowa State College in Ames, Iowa, built and operated the first electronic digital computer. Atanasoff's first computer was "a 12-bit, two-word machine running at 60-hertz wall-plug frequency and could add and subtract binary numbers stored in a logic unit built with seven triode tubes" (Hauptman 2010, p. 8). If you have to update professor Atanasoff of your research finding, what would you write to him in a single page letter?

Activity: Having trouble with math problems?
No problem, Escherichia coli *can help.*

E. coli has been engineered to count. While a lot of work still needs to be done, biologists have already demonstrated the concept and the foundation for *E-coli's* ability to count, which is very important for several reasons.

> *Right now cells, bacteria and otherwise, act as one-and-done detectors. As soon as they detect a particular chemical, it triggers a reaction. This can be helpful for detecting the presence of a chemical, but not useful for measuring the number of times a chemical occurs.* (Bland, 2009, p. 10)

Recently, a group of research scientists from both Boston University and the Massachusetts Institute of Technology successfully programmed E coli to count to three. These scientists believe that with this type of ability which could be used as a read-out mechanism or control switch, the engineered bacteria "could lead to environmental or biological sensors that measure toxins and then self-destruct once their job is done" (Bland, 2009, pp. 2-3).

Conduct internet research to find out:

1. How were scientists able to program *E. coli* to count?
2. How the tools and mechanisms that are used with genes that encode for the bacterial counters:
   a. Could be transferred to other bacteria?
   b. Could be enhanced to program the bacteria to count to higher numbers?

Activity: E. coli *as a Potential Electronic Data Storage Device:*

After counting and solving math problems, scientists are now testing the capability of storing electronic data in *E. coli* that has already been genetically engineered.

> *Cambridge University's student magazine BlueSci reports that researchers from the University of Hong Kong have managed to place 90GB of data into the DNA of a colony of 18 E. coli. The data can also be encrypted by site-specific genetic recombination; a purely natural process that means data can be jumbled up.* (Fish 2010)

Conduct Internet research to find out and answer the following questions:

1. Why do you think this could lead to some pretty enormous storage capacities of electronic data?
2. Why are scientists only trying to experiment with the storing of electronic data in genetically modified *E. coli*?
3. Why do scientists think that bacterial cells and data in them could even survive a nuclear blast?

Activity: Keeping Bacteria Away

Not all bacteria are harmful; indeed, the vast majority of bacteria are harmless. What is more, many of them are helpful for humans, and some others are even *essential* for human life.

Conduct internet research to:

1. Identify the main differences between bacteria that cause disease and bacteria that do not cause disease.
2. Find out the many divergent ways to minimize exposure to possible harmful bacteria that could lead to water and foodborne illnesses that could be deadly to human life.
3. How could a given non-pathogenic bacterium become pathogenic bacterium?
4. Select one type of bacteria from the environment in which humans live such as soil, air, water, and plants and animals around us to search, study, and present.

Bacterial environment and or biome	Bacterial genera	Specifically found in	The economy of the microbe	Its relationship with Human body
Soil				
water				
Air*				
Animal biome				
Plant biome				

* Bacteria don't live in the air but they can be transferred through air. Students are expected to come to this conclusion and/or encounter this information during their research.

Activity: Fecal Transplant

A fecal transplant is a medical procedure that was recently developed and implemented by Australian doctor Thomas J. Borody and his team as an alternative for using antibiotics to treat pseudomembranous colitis which is caused by *Clostridium difficile* infection. While fecal transplant is very simple, safe, and can save thousands of lives, not all doctors use it (Ananthaswamy 2010, MacConnachie, et.al. 2009, Smith 2007).

Conduct internet research to find out:

1. What is a fecal transplant?
2. Why is it conducted?
3. How is it conducted?
4. Why don't all doctors use it?
5. What is your own perspective about fecal transplant?
6. In addition to the treatment of pseudomembranous colitis, is there any other use for fecal transplant?
7. What is the theoretical basis behind fecal transplant or fecal bacteriotherapy?
8. Why do you think this medical procedure to treat pseudomembranous colitis is less popular in North America in comparison to the rest of the world?

Activity: Abundance and diversity of microbial flora in various environments

Sustainable agriculture requires managing both the biota and the crops.

Conduct internet research to find out if there is:

a. Relationship between the use of antibacterial soap and hand lotion and the abundance and diversity of skin microbial flora.

b. Relationship between the use of fertilizers and the diminishing of the abundance and diversity of the soil microbial flora.

Activity: Making Vaccines More Effective

Vaccines are extremely effective at preventing disease. Scientists think that they could work better for more people and against a wider variety of illnesses if we add ingredients that can "supercharge old vaccines and make entirely new ones possible" (Garcon and Goldman 2009, p. 72). It is a fact however, that immunity provided by certain vaccines may weaken over time and thus prevention is always the best option if it can be achieved.

Conduct internet research to answer the following:

1. What is a vaccine? How do they work?
2. What are the common types of vaccines?
3. Compare and contrast the most common types of vaccines?
4. How could vaccines be enhanced to help the immune system? What is the depot effect?
5. Can a "one-size-fits-all" vaccine be possible? Explain.

Activity: Acquiring Normal Microbiota

The human body is teeming with microbial life. Microorganisms that typically colonize the human body (host) without normally causing disease are known as the body's normal microbiota, normal flora, or the indigenous microbiota. However the mother's uterus is an axenic environment and thus babies develop in their mothers' wombs without being exposed to normal microbiota. Conduct research to explain when and how babies start to acquire normal microbiota.

How well do you know your own enterotype?

Joshua Lederberg, who first coined the term "microbiome", argued that microorganisms inhabiting the human body should be included as part of the human genome because of their ability to influence human physiology. A group of microbiologists have reported three distinct ecosystems in the human gut that are not nation or continent specific. They referred to these distinct ecosystems as "enterotypes".

Conduct research to find out:

1. Why do scientists think people can be classified based on their enterotype?
2. What is the significance of recognizing that there are three distinct enterotypes that are not nation or continent specific?
3. From your own perspective, how can this discovery be used to help us to better understand the microorganisms that colonize the human body and how we could better coexist with them?
4. If you were told that this discovery was made based solely on combining twenty-two newly sequenced fecal metagenomes of individuals from four countries with previously published data sets, how would you feel about the discovery?

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PROJECT REPORT

Using Emerging Technologies to Facilitate Science Learning and Civic Engagement

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Abstract

Providing students with meaningful academic experiences in the environmental sciences is challenging in today's urbanized world. Through a combination of activity-based and experiential learning opportunities, today's learners can be motivated to connect course content with other classes and with their daily decision-making processes. Combining technological advancements with traditional pedagogical strategies provides an innovative springboard from which to launch a stimulating science experience for general education non-major students. Civic engagement projects enhance the community-minded thinking of the younger generation while simultaneously serving the needs of local environmental education partners. This paper describes the use of emerging technologies in curricula redesigns, innovative student civic engagement projects, and provides associated evidence of student learning. Two environmental sustainability-focused courses were redesigned and a two-semester sequence was established that linked a hierarchical civic engagement structure to an activity-based curriculum. Based on feedback from "Student Assessment of Learning Gains" (SALG) surveys, students demonstrated significant advancements related to their confidence in understanding core course concepts. Students responded favorably to the course redesigns and generated meaningful projects, which are directly meeting the needs of the regional community. Future goals include expanding student-created biodiversity map projects across the region and enhancing science, education, and outreach by creating web-based interactive tools for regional environmental education partners.

Introduction

"I think that this class is a class of the future and the way it is presented helps students of today's generation learn in a more convenient and realistic way."

- ANONYMOUS STUDENT FEEDBACK

An urbanized world with an exponentially-growing human population that has surpassed 7 billion inhabitants creates challenges for educating today's general education non-science majors about environmental issues, largely due to their lack of connections with the natural world and their common reluctance for science. Additionally, today's learner expects a different learning environment and has new tools available that can be used to enhance the academic experience, both in and out of the classroom (McGee and Diaz 2007). Connecting coursework to other classes and to daily decision-making processes fosters worthwhile learning opportunities, creates engaging science classes, and stimulates passions to become well-rounded individuals who want to contribute in a meaningful way to our democratic society (Burns 2011, Burns 2012).

Delivering meaningful academic experiences to our students is likely the goal of every educator (Dewey 1997, Kolb 1984, Brophy et al 1983, Orr 1992, Zhao & Kuh 2004; Jonassen & Strobel 2006). Although reaching these students can be challenging, frustrating, and difficult, staying current by using technological gadgets and digital lessons can provide an innovative springboard from which to launch new teaching styles and strategies (McGee and Diaz 2007), which allows for the inclusion of high-quality civic engagement opportunities into the curriculum (Jacoby 2009). By linking Education, Ecological Perspective, and Emerging-technologies (eLearning) (the "3 E's", *Figure 1*), an innovative framework that structures the development and evolution of a learner-centered teaching philosophy was implemented. Emerging technologies that include blogs, Wikis, YouTube, podcasting, social tagging, reusable learning objects (RLOs), and social networking websites (Brown 2010), promote higher-order thinking skills (Bloom 1956) from today's students since they can now become producers of information rather than passive observers and consumers of information through technology. Harnessing this productive energy through careful curriculum design leads to profound differences in learner interest, enthusiasm, and confidence.

Prensky (2001a,b) defined "digital natives" as the kindergarten through college students who have grown up surrounded by and utilizing computers, video games, cell phones and MP3 players. He stated that due to the, "ubiquitous environment and the sheer volume of their (students) interaction with it (technology), today's students think and process information differently" (Prensky, 2001a). The immersion in technology-rich environments has impacted the learning preferences of digital natives (Prensky, 2001b). Digital natives prefer quick access to information, multitasking, access to hyperlinked information and choices about the learning process, and synchronous interaction with others (Black et al 2007, Toledo, 2007), which allows these students to move from content-consumers to creators of information for an audience larger than their classrooms (McGee and Diaz 2007) and use higher-order thinking skills outlined by Bloom (1956). While today's students have matured in a world surrounded by technological advancements, many of their instructors are "Digital Immigrants" who are from a different generation and are trying to learn the language and ways of the student, (though there is debate about the use of these terms (Prensky 2001a,b, Toledo 2007, Bennett et al. 2008)). This technological divide should be bridged and students ought to be prepared for their upcoming professional lives by using technologies of the future in today's classroom. As faculty and universities continue to adapt to digital learners, emerging technologies are becoming more integrated into the STEM education learning process (McGee and Diaz 2007, Brill and Park 2008, Brown et al 2010). The incorporation of emerging technologies into the curriculum provides modern, engaging, and learner-centered opportunities for academic growth.

Digital content and web-based applications complement traditional styles of pedagogy (McGee and Diaz 2007), which not only engages students, but also prepares them for their future professional lives (Black et al. 2007). Students expand their community-minded thinking by producing high-quality projects that directly benefit informal environmental science education centers through civic engagement opportunities. Kolb (1984) defined learning as "the process whereby knowledge is created through the transformation of experience." Active learning is defined as, "instructional activities involving students in doing things and thinking about what they are doing" (Bonwell & Eison, 1991, p. 1). Students should not just be passive receivers of knowledge, skills and dispositions, but should be in engaged in reading, writing, discussions and problem-solving. Stice (1987, as cited in Stalheim-Smith, 1998) adds that active learners remember more when their learning activities are combined with an action such as teaching others. Active learning includes moving the learning from faculty presentation of materials to students understanding, applying, analyzing, synthesizing and evaluating the materials. Emerging technologies give the educator the necessary tools to complement active-learning classrooms and improve content delivery, which has the following benefits for curricula redesigns:

1) Engages students in the learning process through the use of interactive web-based techniques;

2) Links innovative pedagogy in the STEM education classroom to student uses of everyday digital entertainment devices;

3) Enhances student retention of course material which translates into improved academic successes.

Two popular pre-existing general education non-science major courses at Florida Gulf Coast University (FGCU) are "*Environmental Biology: Ecosystems of Southwest Florida*" and "*Marine Systems: Introduction to Oceanography*". Both were redesigned to include innovative teaching strategies and to provide course-based civic engagement opportunities. The former is a regional basic ecology course designed to introduce students to ecological concepts, ecosystems structure and function, and the scientific process. The latter is a global-scale course that uses our coastal locations as relevant case study opportunities and investigates major disciplines associated with oceanography, human impacts on the marine world, and the scientific method. Both courses include components designed to relate current topics and environmental sustainability discussions to the daily lives of students. Experiential- and activity-based learning strategies are used to create learner-centered environments that maximize interest, engagement, and content retention. Integrative themes (for example, leading students on visits to local natural areas and relating discussions to water flow from the interior ecosystems to the coastal estuaries during the "Journey Down the Corkscrew Watershed") and guiding questions weave difficult concepts together over time and facilitate student connections across the curriculum. Both course redesigns incorporate technological learning strategies, which exemplifies key components of the FGCU Mission Statement.

Engaged student citizens have opportunities to connect classroom content to serving the needs of the local community. A student who is more connected to a community is more likely to want to help that community. Institutions of higher education were recently challenged in the Campus Compact's Presidents' Declaration on the Civic Responsibility of Higher Education to "become engaged, through actions and teaching, with its communities". While there are many models for embedding civic engagement projects into a course curriculum (Jacoby 2009), in this case, opportunities were woven into the actual fabric of the course by linking student projects with the various regional environmental organizations and partners who assist with our classes. Students are given the opportunity to create high-quality, technologically-advanced projects that directly serve the educational, ecological, and economic needs of our community partners. These student projects also stay consistent with the integrative themes of the courses.

Environmental education, by nature, is an interdisciplinary subject that relates directly to real-world scenarios and connects across a larger context with other classes. Designing appropriate curricula to enhance learning experiences is a challenge, but with careful consideration, it can be a very rewarding experience for instructor, students, and the surrounding community (*Figure* 2). The SENCER (Science Education for New Civic Engagements and Responsibilities) approach to pedagogy aims to apply the science of learning to the learning of science while embedding civic engagement into the learning process. Two existing courses were redesigned using the SENCER approach to help students connect their STEM learning to real-world examples and to their other courses by embedding emerging technologies, interactive GIS/mapping exercises, and civic engagement opportunities to help advance the connection between an educated citizenry and a functioning democracy. This paper describes the role of emerging technologies in a learner-centered approach to course delivery, explains the curriculum redesign for a two-course sequence, including a hierarchical civic engagement structure embedded within the multi-semester academic experience, and provides results from "Student Assessment of Learning Gains" (SALG) surveys that demonstrate evidence of student learning.

Curricula Development and Methodologies

Most of us spend much of our time pondering how to deliver course content, how to make impacts on the students' lives, and how to keep it all original. We want to passionately guide our students through their academic journeys, but, we realize that today's learners are different in that they have been immersed in a technologically-advanced world that influences how they learn. Today's educators can not only stimulate students *in* the classroom but also are able to make their learning experiences technologically-rich and engaging *outside* of the classroom by using digital content and reusable learning objects (refer to Box 1: "Description of a Teaching Innovation: RLOs"). The creation of activity-based curricula that focus on experiential learning, critical thinking, and integrative themes makes for a rich learning experience and helps foster community-minded individuals (*Figure 3*).

Evolution of class activities occurs semester-to-semester, but within the core academic experience are active-learning modules and breakout groups that focus on hands-on field collection and science discovery labs, campus nature wetwalks, capstone projects, guest speakers, web-based self-created learning modules, and off-campus field excursions to regional sites. Using the mosaic of interacting inland and coastal ecosystem types across the southwest Florida landscape as our natural backdrop, environmental sustainability is the unifying theme during our class "Journey Down the Corkscrew Watershed." The teaching philosophy focuses on student learning needs while it also provides a rich, stimulating experience based on personal passions and experiences.

Students leaving this course sequence should be thoughtful, engaged citizens who gained an ecological perspective. A rigorous curriculum keeps students motivated by providing them with the necessary fundamentals and learning opportunities early in the semester, so that they may apply these concepts and think deeper about relevant topics later. Enhancing study skills and critical thinking strategies is an important first step. Interactive discovery field labs provide the opportunity for students to understand the scientific method and appreciate how science is conducted, so that they may understand the difference between sound science and junk science. Research skill development is crucial in these classes and students practice finding and interpreting primary literature from reputable science journals. Improving student communication skills (written, oral, and digital) are important developmental needs, and students achieve these skills early in their academic career during this course sequence. During a typical semester a variety of learning opportunities designed to meet the needs of today's modern learner are made available to students (*Table 1*). These learning opportunities not only match the needs and desires of "Digital Natives" but map to common learning outcomes for General Education students. Embedding appropriate emerging technologies and matching them to the proper class exercises maximizes student engagement and caters to varying attention spans. The benchmark for academic success is high and encourages students to reach their maximum potential and productivity. The most talented students are challenged, but nobody is intentionally left behind.

The role of instructor might best be labeled as "academic facilitator" who guides students through their personal academic journey, while helping them refine their personal learning strategies. Classes are generally lively and interactions with small breakout groups of students are essential. These groups are asked leading questions and are dropped "thought bombs" for the group to discuss and consider. This method also allows the instructor to assist students real-time who might need a bit more focused attention. Rather than dumping bullet points of knowledge into a student's head and hoping it stays, students are expected to think deeply about what they are learning so that they may seek out the necessary tools to help them answer their questions, which should enhance their retention of course material. The use of emerging technologies provides the necessary freedom because formal lectures can be delivered online and accessed in myriad ways before, during, and after class. It is very rewarding to have an engaged, noisy, borderline-chaotic classroom where students are discussing, implementing, and creating!

eLearning Features

To enhance student engagement in the learning process outside of the classroom, web-based learning modules, activities, and communication tools are highly effective (McGee and Diaz 2007). Video and audio podcasts allow students to take the instructor with them wherever they go. "Digital Natives" are multi-taskers who enjoy having access to course material at times that suit their schedules, which means providing online lectures, field excursion descriptions, and guest speakers who might engage these students while their earphones are plugged-in (Toledo 2007). Discussions using Twitter, where the class is sent a weekly "tweet" and students respond at their leisure, are incorporated to facilitate discussions based on their tweets, responses, and feedback, which provides for more profound class interactions and gives reluctant students a much-needed voice (Brown 2010). Most recently, a library of digital Reusable Learning Objects (RLOs), unique to the redesigned courses and based on strong pedagogical models (Black et al 2007), were created and are easily accessible by students via online learning management platforms (refer to Box 1: "Description of a Teaching Innovation: RLOs"). A series of regionally-relevant Geographic Information System (GIS) lab exercises are embedded within the course redesigns to serve as visualization exercises of core academic concepts. It is important that students use and create, so students are encouraged to create webpages, record podcasts, and employ RLOs for their own class projects and service-learning materials (*Figure 4*).

Civic Engagement Connections

Embedding civic engagement opportunities into the academic experience provides profound learning opportunities for students. Learners take the knowledge they have gained in the classroom, reflect on that learning, and apply it to meaningful projects that directly benefit the local community. Establishing opportunities early in a student's academic journey will make for a productive experience throughout the process. For this sequence of course retrofits, students are partnered with the same regional environmental site locations that are visited during class field excursions. Multiple student-driven projects linking the "Three E's" (Education, Ecology, and eLearning) were created that serve the needs of these community partners.

It is important to organize the projects so that students can succeed and not be burdened by complicated tasks. Before the project begins, students must contact their host agency representative and create a project proposal. Students are asked to complete a minimum of 5 hours of outside service-learning time for their entry-level projects and are generally clustered into small groups to maximize effort-per-individual. Following completion of the project preparation and direct interaction with regional partners, students present orally to the class and highlight their group's effort. The regional partners and host agencies are invited to this important event. As a final deliverable, students submit a high-quality reflective essay that explains how the project helped them connect learning to real-life scenarios.

A structured hierarchy introduces students to the value of service-learning early in their academic careers which assists them by embedding opportunities throughout their entire time as an undergraduate. Because of the hierarchical structure, students add valuable life skills to their service-learning opportunities. Upon completion of both entry-level classes, students can elect to join "The Straw Hat Brigade" and serve as supervisors for the next semester's student groups. Students are recognized because of the straw hats commonly worn in Florida to keep the sun off of one's face while doing field-work. Members of this new "brigade" of student leaders furthers their commitment to community projects by working directly with the instructor and serve as communication facilitators between student groups, regional partners, and instructor. They may also lend advice, provide peer-review, and give assistance to specific projects. Motivated students may even create new projects that directly interest them in relation to their academic majors. As students progress through their academic careers, they may advance their service-learning skills by joining university-level programs aimed at providing rich experiences (*i.e.* the E.A.R.T.H. Program) instead of haphazard completion of required hours for graduation. The E.A.R.T.H Program is a recently-implemented faculty-led interdisciplinary network of mid to high-level students who are combining structured service-learning projects with work-study opportunities and internships. A capstone course, called *University Colloquium*, is required of all students, where they reflect on their complete environmental education experience and perform 10 hours of service-learning with an environmental organization. Lastly, graduate student assistants play an important role with communication efforts, scheduling, and project facilitation. The hierarchical strategy and its relation to existing university requirements is explained in Figure 5.

A primary objective in this course sequence is for students to make positive contributions to the community based on their knowledge from the course, newly-acquired skills and ecological perspective. Civic engagement projects help students foster a sense of respect and responsibility, help them make connections between course content and real-world scenarios, and directly enhance the surrounding communities. A common theme these student-driven projects share is that they link ecological perspective and community education through the use of emerging technologies (*Table 2*). Students are producers of educational content rather than merely passive consumers of information. Community-minded individuals leave this two-course sequence and have made positive contributions to the world around them.

Student Assessment and Evidence of Learning

Assessment of student learning is important when redesigning curricula. The SALG-(Student Assessment of their Learning Gains) is used to help gather baseline data related to students' self-assessment of improved academic successes. The SALG tool is an online survey that students take before the semester begins in the form of a pre-SALG and after the semester is completed as a post-SALG. A wide variety of question types are asked and students rank their personal attitudes and confidence related to each question. Additional free-writing typed responses are also made available to students. This is a valuable feedback opportunity to demonstrate student learning has taken place and to gain student perspective on course content. The SALG surveys provide a synopsis of the course retrofits, by summarizing the "Guiding Question", primary "Student Objective", and expected learning outcomes for each course. The teaching philosophy and methodologies are validated when looking at the survey results refer to Box 2: "SALG Surveys").

Figures 7 and 8 are summary graphs that illustrate the results from the pre- and post-SALG surveys. In relation to all major course concepts, students enter the course "somewhat" confident in their abilities and understanding of these core concepts, but leave approaching "a great deal" more confident with their understanding. These results demonstrate that students increased their confidence in the course material during the semester. Specific questions from the SALG that directly relate to the components of the course "Guiding Question" have been chosen, which are important measures of student learning and academic success. This type of feedback improves the overall course delivery and helps refine the curricula based on student perspectives.

An assortment of conventional measures of student feedback are obtained, including pre/post tests, project feedback, traditional SAI (Student Assessment of Instruction surveys), etc. to complement the SALG surveys. Each semester, students are given the opportunity to anonymously state what they most enjoyed about the course and what can make the course even better. Such student responses improve the class every semester as lessons can be fine-tuned and calibrated to match students' needs. Students are responding positively to the course redesigns and are demonstrating increased confidence in all categories measuring learning gains:

> "Project-based learning helped me a great deal, and was refreshing after other classes filled with just reading and tests." *Marine Systems – SALG*

> "I really enjoyed the teaching method and the way the professor was passionate about the subject and the way he passed it on." *Environmental Biology – SAI*

Future Plans and Goals

Students will continue to be recruited into "The Straw Hat Brigade" program, which provides them with meaningful service-learning opportunities, leadership skills, and supervisory roles. A major goal of this initiative is to create highly-advanced projects that help general education students improve their written, oral, and digital communication skills while simultaneously gaining an ecological perspective that relates to their daily decision-making processes. To accomplish these goals, student biodiversity map projects across the region will be expanded to enhance science, education, civic engagement, and outreach by creating web-based interactive maps for regional environmental education locations. Students will also present their projects at different venues to build momentum for the entire program and to gain valuable networking skills in professional settings.

Another goal is to work with environmental educators across the country who teach similar classes. Together, we can develop and publish a SENCER Model Course based on this course sequence redesign that would connect students across the United States via a web-based class structure, where each institution is located near a coastal watershed. A strong interdisciplinary program that is highly collaborative has the potential to expand student awareness of critical environmental issues we face today. Student exchange programs would be included to foster a sense of respect for other locales. Civic engagement strategies, educational technology techniques, and environmental awareness opportunities will be embedded within the proposed model course organization.

Conclusion

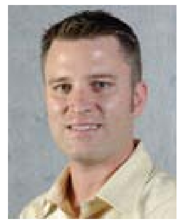
Students begin their academic journeys with varying degrees of ecological knowledge and connections to the natural landscape. Coupled with an apprehension toward science, environmental education can be a challenging endeavor for today's educator in a highly politicized and urbanized society. Finding new ways to stimulate and reward learners is an appropriate response by educators.

Experiential and activity-based learning opportunities enhance the environmental education experience for general education non-major students. Integrative themes woven through the fabric of the course helps students draw natural connections to difficult course content and concepts. This two-course sequence and associated service-learning hierarchical track strategy is improving the overall experience for students. Students demonstrated increased comprehension of all core course themes related to sustainability, ecosystems structure and function, natural goods and services, the relationship between these concepts, and how studying these subjects helps address real-world issues. Students responded favorably to both the approach and to the civic engagement components by creating community-friendly projects that benefit regional environmental education partners. Students leave this track as educated and engaged citizens who serve the needs of their local communities.

Tomorrow's classroom will look much different spatially and technologically. In fact, that classroom of the not-too-distant future and the academic tools in it may not even exist yet. As faculty members, we must continue to provide our students with the technological skills they need to succeed professionally, even if we, ourselves, are unsure of that technology. We must challenge ourselves and use innovative teaching methods to reach today's learners. I caution that simply throwing technology at our students is not sufficient. We need further evaluation and assessment of incorporating emerging technologies in the classroom to ensure that these tools are academically sound and actually facilitate student interest in the learning process (Austin 2009). Choosing the right technology to accompany sound pedagogical methods (McGee & Diaz 2007, Brill & Park 2008) should be carefully done so students can communicate effectively, collaborate during the learning process, and think critically about course topics. A primary goal of this STEM education course sequence redesign was to connect learning to social issues through innovative teaching strategies by matching appropriate emerging technologies with teaching methodologies and with civic engagement projects. Entry-level general education STEM courses, like the track described in this article, provide us with the opportunity of exploring these emerging technologies in our curricula.

The complete academic journey during a semester is significant and a great deal of effort is spent trying to understand the needs of students and what must be done to effectively address those needs. The inclusion of active-learning strategies and emerging technology into the teaching philosophy engages students in and out of the classroom, exemplifies the goals of today's universities, and provides ongoing and rewarding interactions with students. As educators in a democratic society, we have a serious role and responsibility to prepare the younger generation for their professional lives ahead of them (Burns 2011, 2012). The late Steve Jobs, co-founder of Apple, suggested that our outdated education system could be greatly improved if each student had individually-tailored digital learning resources that included just-in-time assessment of student abilities (Isaacson 2011). The strategies, methodologies, and activities chosen in this course sequence redesign reflect passions for education, ecological research backgrounds, and interests in innovative eLearning methods. By interjecting our passions into the academic journey, we just might have a chance to assist students in drawing meaningful connections with the natural landscape in this highly-urbanized system and help them overcome their apprehensions about learning science.

About the Author



David Patrick James Green is an Instructor in the Department of Marine and Ecological Sciences at Florida Gulf Coast University. His research background has primarily been focused on fish community structure and function along salinity gradients in the Florida Everglades. He is currently retrofitting introductory science courses using the SENCER approach to pedagogy and assessing the effectiveness on student engagement and learning. Through hierarchical civic engagement projects that incorporate emerging technologies for delivery to the general public, his students create and provide high-quality educational materials to regional informal science centers that have an ecological perspective. David recently received the FGCU "Excellence in Teaching Award" and the FGCU "Presidential Award for Best Teaching Practices" as a result of his SENCER-related activities.

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APPENDIX 1

Description of a Teaching Innovation: RLOs

A recent study by the Educause Center for Applied Research reported that nearly 78% of students download music and video during an average of 18 hours per week spent online (Salaway & Caruso 2007). Educators can assist students with exploring the educational benefits behind such entertainment gadgets. As faculty and universities adapt to digitally-based learners and learning environments, web-based technologies are becoming integrated into the learning process (McGee and Diaz 2007). This summary explains an emerging technology called "Reusable Learning Objects" (RLOs) that is currently being implemented and tested in *Environmental Biology* and *Marine Systems* classes (Brown et al. 2010).

Since formal lecture time is lost as a result of active-learning practices, including outside lab activities and off-campus site visits, digital RLOs complement the academic experience of a student by providing an enhanced online interactive learning environment (Black et al. 2007). These self-produced, creative presentations provide students with interactive lectures and real-time quiz assessments that can be continually accessed at any time or place (*Figure 6*). Of the 54 students recently polled, 64% used the RLOs regularly, and of that 64% all of the students stated that the RLOs helped them succeed academically.

Benefits associated with incorporating web-based RLOs include:

- Breathing new life into tired Power Point slides by adding animated figures, text, and illustrations;
- Adding assessment tools and quizzes for student self-checks during real-time studying;
- Making digital educational content available for resource-sharing with other educators;
- Converting to various formats which allows for easy upload to learning management systems and tablet computers;
- Freeing-up classroom time for activities other than lecturing, but still delivering core academic concepts.
- Engaging, technological options provide a fun and interactive academic experience for students. Experimenting with new teaching techniques allows the instructor to maintain an inventive learning environment, while simultaneously providing the students with tools they need to succeed academically. An engaged student is a successful student, so why not let them have access to the course wherever they go?

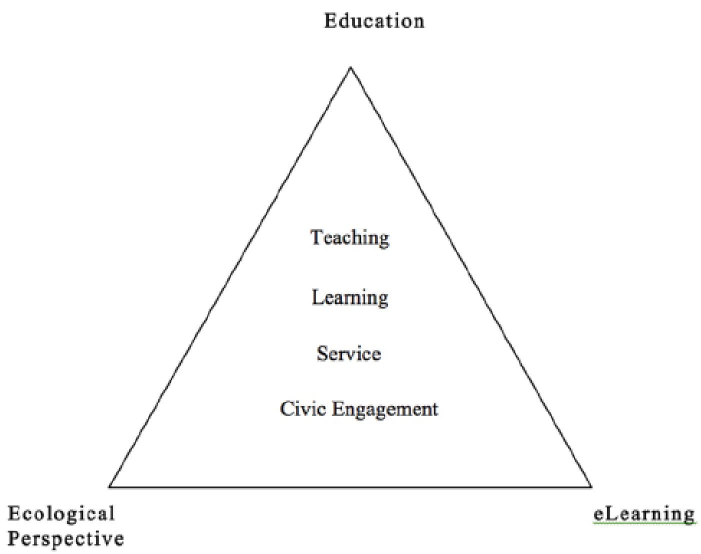

FIGURE 1. The interconnection of the "3 E's" (Education, Ecological Perspective, and eLearning) guides the development and evolution of the teaching philosophy, enhances student engagement in the learning process, and facilitates professional growth.

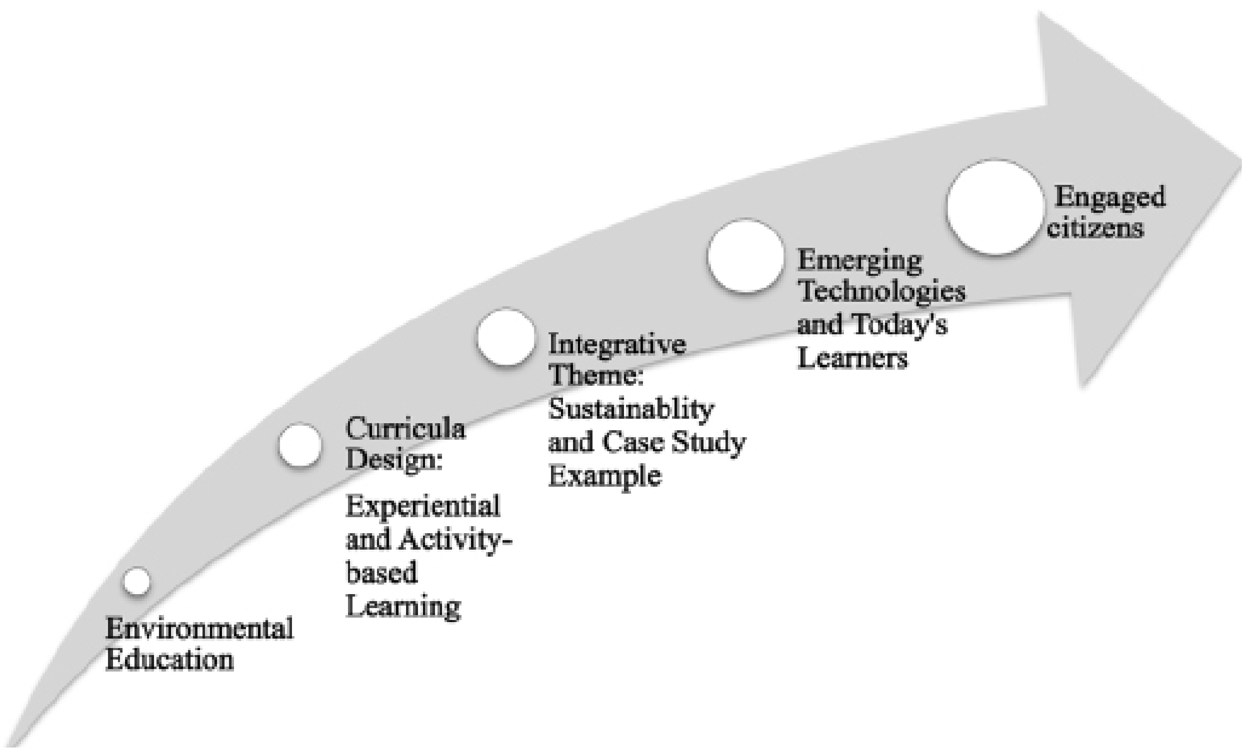

FIGURE 2. From non-science majors to engaged citizens with ecological perspectives. The overall goal of environmental education is enhanced by experiential and activity-based learning opportunities. An integrative theme of the course sequence, environmental sustainability, is introduced by outlining the specific case study involved, which is called "A Journey Down the Corkscrew Watershed." Next, the incorporation of emerging technologies into the environmental education curriculum prepares today's learners for tomorrow's professional world. Lastly, civic engagement projects that include emerging technologies and link regional partner collaborations with students tie everything together, which allows the learner to reflect on the learning process and give back in a meaningful way to the local community.

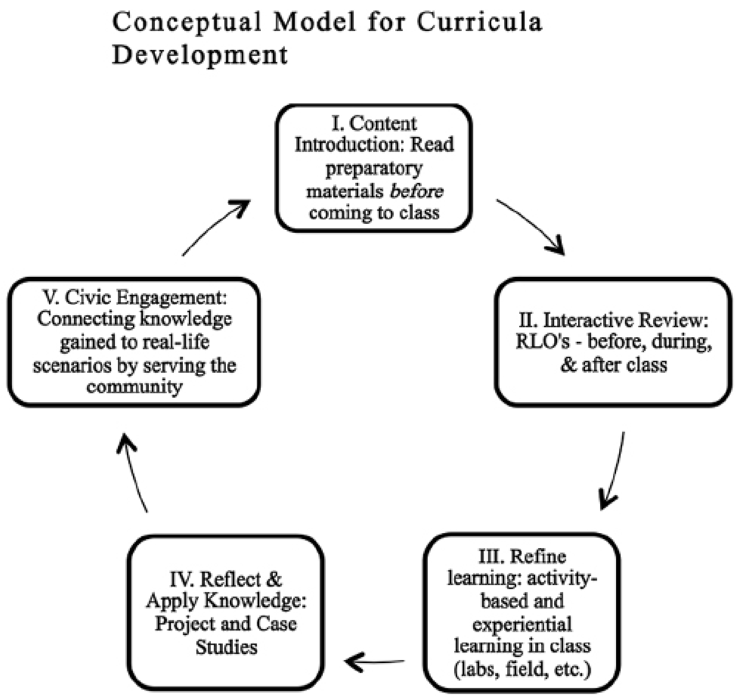

FIGURE 3. Conceptual Model for Curricula Development The "Curricula Development Conceptual Model" illustrates the linkages between the teaching philosophy and course delivery: Emerging technologies, activity-based, experiential, and project-based learning styles facilitate student engagement and content retention, while civic engagement opportunities are embedded to connect course content to real-life scenarios.

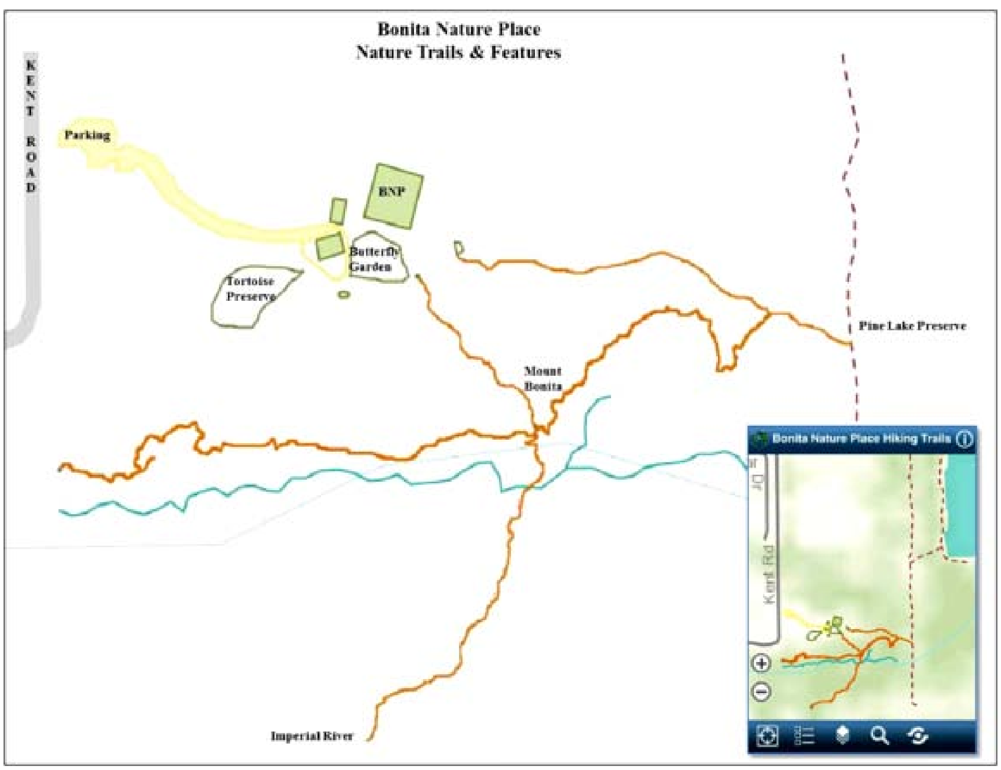

FIGURE 4. The screenshot is an example of a student-created project. This particular endeavor began as a service-learning project where groups of students created nature trails for a regional nature center. Following trail construction, new groups of students mapped them using handheld GPS receivers and cloud-based GIS software. Most recently, groups of students have begun embedding education content (i.e. videos, learning objects, pictures, etc.) into the interactive version of the GIS map, which is made available to the general public using smartphone technology (as seen in the smaller inset image). Such projects relate to the "3 E's" by educating the public about ecology while using emerging technologies as tools.

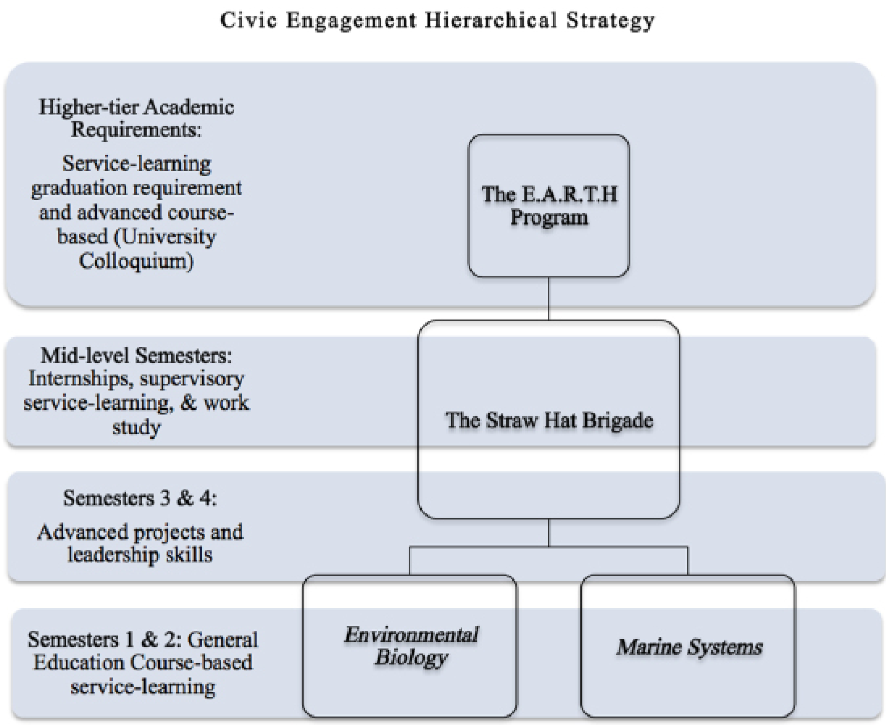

FIGURE 5. Civic engagement hierarchical strategy
The hierarchical strategy implemented into the general education course sequence. Students are introduced to course-based service-learning opportunities during their first two semesters. They advance through the hierarchy and can connect future service-learning opportunities with advanced projects and responsibilities as part of "The Straw Hat Brigade". This sequence feeds into mid-level and higher-tier requirements and establishes a complete "track" of service-learning opportunities for students.

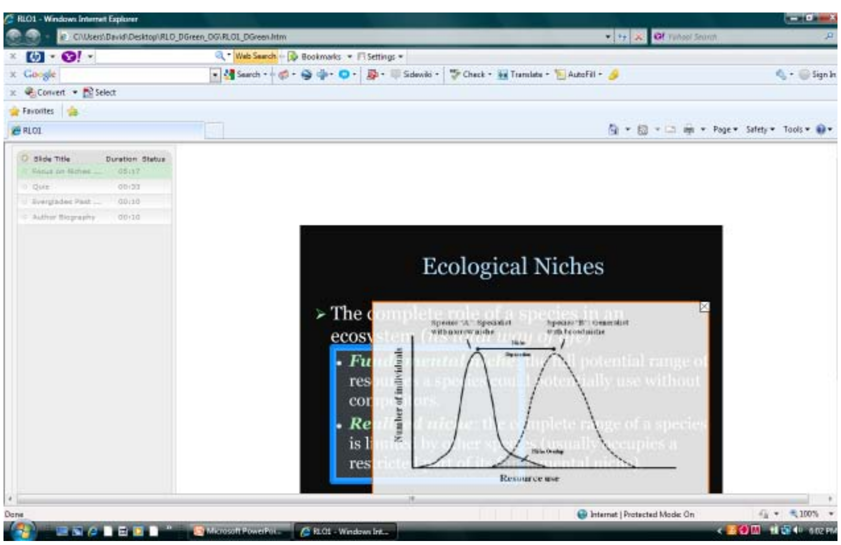

FIGURE 6. A screenshot of a digital reusable learning object (RLO) as seen when accessed from a typical web browser. The navigation pane appears on the left and is where students can move from one component to another. Also evident in this navigation panel is the "quiz" function that allows for real-time feedback to students. The image displayed is actually an interactive image where a cursor has scrolled over a definition (in this case, the definition is related to ecological niches) and a second image appears that helps the student visualize the text they just read. A digital RLO also contains corresponding audio. To interact with an actual RLO, I encourage the reader to visit the following webpage and scroll to the bottom where it reads "Reusable Learning Object Example: Ecosystem-based Management and the Florida Everglades". http://faculty.fgcu.edu/dgreen/

TABLE 1. Descriptions of learning opportunities and the relationship to "Digital Native" (student) education enhancement and needs. Educational needs (or desires) of modern learners (with abbreviations) include: **O**: Provides ownership of learning experience; **AS**: Engages learners with varying attention spans; **D**: Digital delivery of content. Traditional learning outcomes (with abbreviations) include: **C**: Enhances Communication Skills (Oral, Written, and/or Digital); **CO**: Increases Ability for student to collaborate with peers; **CT**: Critical-thinking exercises embedded; **HOTS**: Students-as-producers of content (Higher Order Thinking Skills – Bloom's Taxonomy).

Learning Opportunity	Description	Matching Education Needs of "Digital Natives"	Mapping to Traditional Learning Outcomes for "Digital Natives"
Presentations (non-traditional lectures, web-based, and interwoven within-class exercises)	These just-in-time presentations use PowerPoint, whiteboards, interactive discussions, and other techniques to engage students.	AS, D	C, CO, CT
Guest speakers	Regional experts connect students with real-time content. A digital library of recorded guest speaker presentations is now available and used for follow-up projects.	O, D	C, CT, HOTS
Within-class breakout group projects and presentations	Interactive exercises and breakout group opportunities facilitate discussions, help with comprehension of difficult subject matter, and retain student attention.	O, AS, D	C, CO, CT, HOTS
Guiding Questions	The semester focuses on a central "Guiding Question" and every class activity addresses this integrative question throughout the term. Each individual class session also begins with a "Guiding Thought of the Day" to help students make connections.	O, AS	CT
Capstone projects with written, oral, and digital communication elements	Students summarize all major course concepts in a webpage format, which enhances communication and teamwork skills.	O, D	C, CO, CT, HOTS
Lab exercises	Opportunities to describe the scientific method in action, to provide encounters with the local habitats, and to help explain/visualize key concepts are provided.	O, AS	C, CO, CT, HOTS
Field excursions	Foundational experiential learning opportunities at local sites (both on and off campus) are explored as a class. There are walk-and-talk sessions, fieldwork opportunities, identification exercises, and more.	AS	CT
Student presentations	During the semester, a variety of presentation types, including formal typed lab reports, impromptu oral presentations, formal presentations, web-based presentations, etc. are used to enhance student confidence with their presenting skills.	O, D	C, CO, CT, HOTS
Reflective journal exercises	Students make observations, reflect on those observations, and apply this knowledge to course assignments and tasks.	O, D	C, CT, HOTS
Online learning modules	These serve as supplementary academic opportunities so that students have access to class outside of the normal meeting times.	AS, D	C, CT
Civic engagement projects	These projects enhance service-learning for students and directly connect our course content to opportunities that benefit regional environmental organizations.	O, AS, D	C, CO, CT, HOTS

TABLE 2. Civic engagement projects serve the needs of local budget-limited nature centers and informal science education outlets by providing educational content for public use. Students, using higher-order thinking skills, are producers of interactive web-based and smartphone-enabled projects. All projects relate to the "3E's" described in this paper: Education, Ecological Perspective, and Emerging Technologies, so that "Digital Natives" are given the tools they need to succeed in their future professional lives.

Civic Engagement Project	Educational Content Provided	Ecological Perspective Gained by Members of Community	Emerging Technologies Used by Students
Interactive nature trail maps	Education and outreach related to respective nature centers and trail systems	• Local ecology and ecosystem structure/function • Human impacts to the natural landscape • Importance of coastal watersheds	GPS handheld units, Cloud-based GIS map-making software, YouTube Videos, QR Codes, Webpage construction
Botanical maps	Tree species identification, location, and associated ecological data	• Local ecology and importance of native tree species • Tree canopy percent coverage estimates for urban nature centers	GPS handheld units, Cloud-based GIS mapping software
Interactive campus research projects map	Communication tool for current and past scientific research projects on campus, people involved, project summaries, and associated data	• Scientific method • Ecology projects and data collection techniques	Cloud-based GIS software, Webpage construction

SALG Surveys

SALG Survey #1: Environmental Biology

"Guiding Question" for this course:

How can tomorrow's generations of all southwest Florida inhabitants continue to benefit from the natural goods and services a healthy coastal watershed provides, by better understanding *our* role as citizens *today*?

Primary Course Objective:

Students will be able to positively influence southwest Florida and global communities to make evidence-based decisions regarding human use and impacts of coastal watersheds and ecosystems.

To form educated responses to the "Guiding Question", students must demonstrate an advanced understanding of:

1. The definition of sustainability;
2. The ecology of a coastal watershed and human benefits / influences;
3. The role of civic engagement and the importance of an educated citizenry;
4. The connectedness of these main course concepts with their daily lives and decision-making processes.

SALG Statement Descriptions:

"Presently, I understand the following main concepts that will be (or were) explored in this class:

1.1.1 Sustainability
1.1.2 Ecosystem Structure and Function
1.1.3 Natural Goods and Services
1.2 The relationship between these main concepts
1.5 How studying this subject helps people address real-world issues
1.6 How civic engagement activities help connect course content to real-world scenarios."

SALG Response Choice Scale of Agreement:

1: N/A 2: Not at all 3: Just a little 4: Somewhat
5: A lot 6: A great deal

SALG Survey #2: Marine Systems

"Guiding Question" for this course:

Given the current degree of human impacts on the marine world, how can tomorrow's generations of all inhabitants continue to benefit from the natural goods and services a healthy marine system provides, if *we* better understand *our* role as citizens *today*?

Primary Course Objective:

Students will be able to positively influence southwest Florida and global communities to make evidence-based decisions regarding human use and impacts of coastal and marine areas/resources.

To form educated responses to the "Guiding Question", students must demonstrate an advanced understanding of:

1. The definition of sustainability;
2. Human impacts and reliance on the marine world;
3. The major disciplines related to marine science;
4. The role of civic engagement and the importance of an educated citizenry;
5. The connectedness of these main course concepts with their daily lives and decision-making processes.

SALG Statement Descriptions:

"Presently, I understand the following main concepts that will be (or were) explored in this class:

1.1.1 Sustainability
1.1.2 Natural Goods and Services
1.1.3 Marine Geology
1.1.4 Marine Chemistry
1.1.5 Physical Oceanography
1.1.6 Chemical Oceanography
1.1.7 Marine Biology / Ecology
1.1.8 Human impacts on the marine environment
1.2 The relationships between those main concepts
1.5 How studying this subject helps people address real world issues

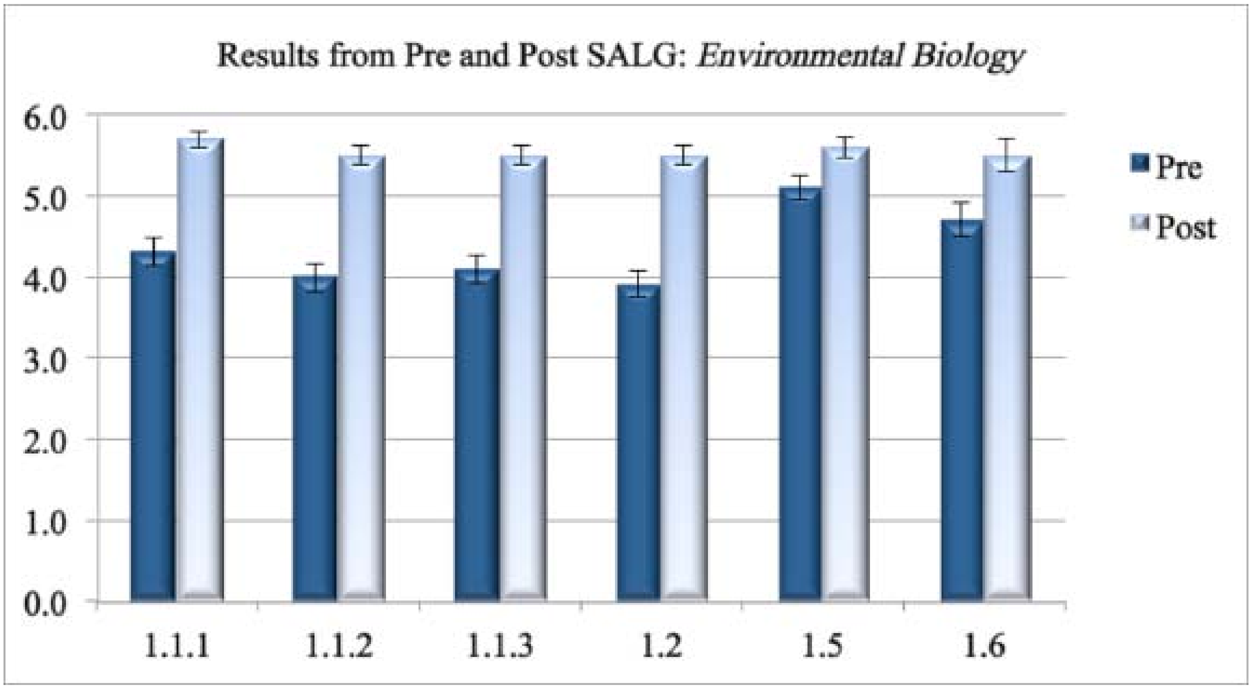

FIGURE 7. SALG results are displayed (pre-SALG and post-SALG; mean values / SE are reported; n = 28) from the Fall 2011 *Environmental Biology* class. Students responded to the SALG Statements listed below and had a choice of responses ranging from "Not at all" to "A great deal" (also listed below). This subset of SALG statements relate directly to the "Guiding Question" and core concepts for the course. Students clearly leave the class feeling more confident in their understanding and demonstrate significant learning gains.

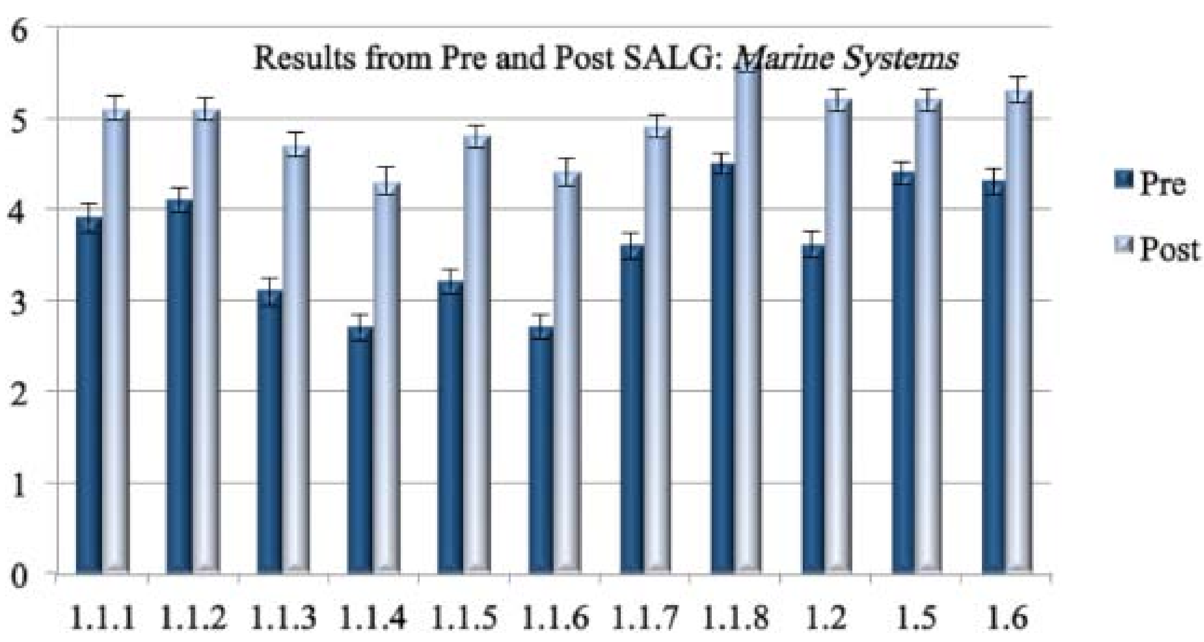

FIGURE 8. SALG results are displayed (pre-SALG and post-SALG; mean values / SE are reported; n = 58) from the Fall 2011 Marine Systems class. Students responded to the SALG Statements listed below and had a choice of responses ranging from "Not at all" to "A great deal" (also listed below). This subset of SALG statements relate directly to the "Guiding Question" and core concepts for the course. Students clearly leave the class feeling more confident in their understanding and demonstrate significant learning gains.

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PROJECT REPORT

Full Immersion: The Chesapeake Bay Watershed as an Environment for Learning Science in a Civic Context

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The Bay as a Rich Context for Learning

The Chesapeake Bay, North America's largest estuary system, is a case study in the connections between science and civic engagement, the power of science to provide key insights into challenging issues, and the limitations of science to effect change in contested civic spheres. The Bay's watershed, which encompasses more than 64,000 square miles and parts of six states in the Eastern U.S., is home to more than seventeen million people whose activities within the watershed affect the quality of water in the Bay and therefore the biota that live there (Lippson and Lippson 2006). Waste water treatment, storm water runoff, confined animal production facilities, energy extraction and use (e.g., gas fracking and coal-fired power plants), and countless other influences have earned the Bay a grade of D for overall health (thirty-one of 100 for Bay Health Index; CBF 2010). These pollutants cause environmental changes such as oxygen-deficient dead zones, sedimentation, and exposure to endocrine disruptors that in turn affect Bay fauna such as blue crabs (*Callinectes sapidus*), Eastern oysters (*Crassostrea virginica*), and game fish species. These species are integral to the Bay's health, and therefore declines in their populations affect not only the ecosystem but also the local economy (CBF 2012).

The watershed is a stage set with complex and controversial civic issues in which a diverse ensemble of actors has roles: watermen, farmers, industrialists, local officials, recreational users and tourists, state- and regional-level leaders, and the millions of other citizens who live in the watershed. These issues and their interrelated influences are rich in scientific content: water chemistry, biogeochemical cycles, global climate change,

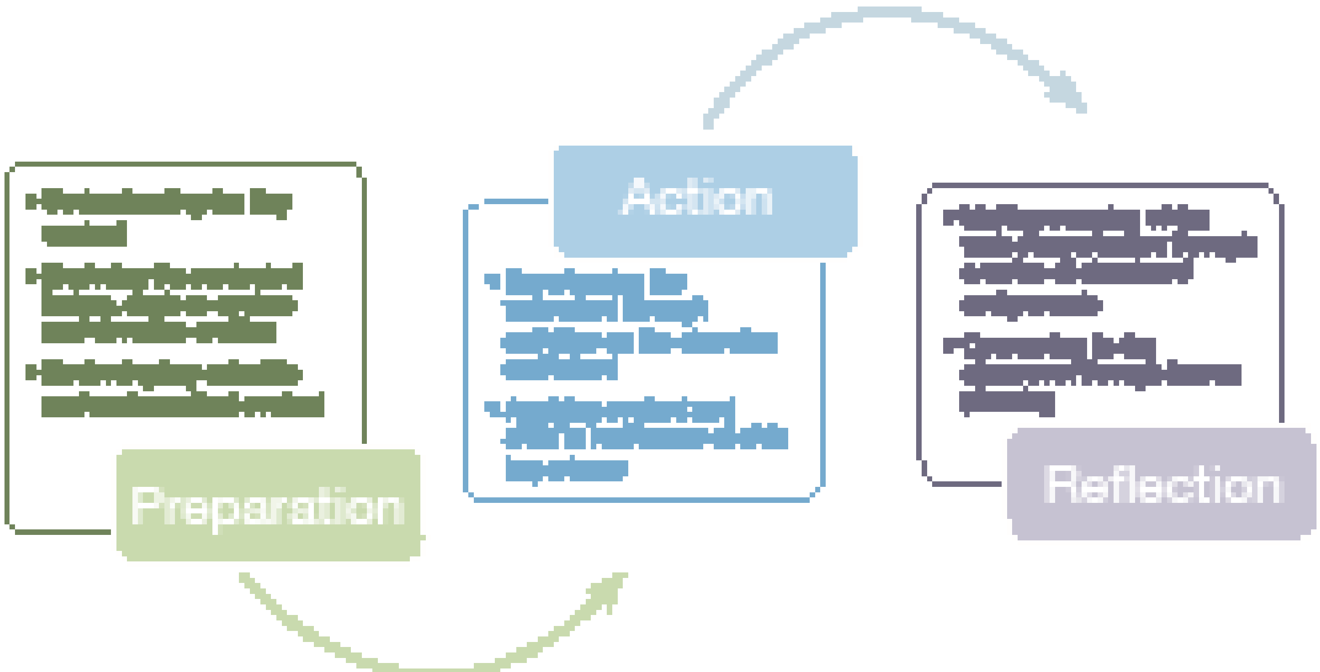

FIGURE 1. Overview of a national model for environmental education, "Meaningful Watershed Educational Experiences."

population dynamics, etc. Leaders in the environmental sciences argue that these issues require urgent action: "Nothing could be more short-sighted than apathy, lax enforcement, or fear mongering. The time for action and stewardship is now" (CBF 2010). In response to similar calls over time, including the multi-state *Chesapeake 2000* agreement (CBP 2000), environmental educators have sought to effect change in the Bay's watershed by better preparing teachers to engage their K-12 students in Meaningful Watershed Educational Experiences (MWEEs; CBPEW 2001). Three-phase MWEEs (Fig. 1) are place-based activities designed to not only foster understanding of the Bay and a sense of connection to it but also to provide an impetus to take action on its behalf. In Virginia, Chesapeake Bay Academies serve as a venue for professional development for K-12 teachers seeking to learn about the Bay and develop MWEEs for their own classrooms. Each year the Virginia Resource Use and Education Council (VRUEC) sponsors approximately six Academies and provides financial support for them through subawards of National Oceanic and Atmospheric Administration funding.

In hosting our first Bay Academy at Longwood University in 2011, we expanded the reach of our long-term Science Education for New Civic Engagements and Responsibilities (SENCER) project to include in-service teachers.[1] Our Bay Academy, which we called Summer of Learning: Science Teachers Investigating the Chesapeake Environment (SOLstice), also marked an expansion of the Academies' reach by including pre-service teachers in addition to its traditional in-service teacher population. Our key goals in developing SOLstice were to use a SENCER approach to structure a unique learning experience for pre- and in-service K-12 science teachers. Focused on authentic interdisciplinary investigations of the Chesapeake Bay watershed, SOLstice facilitated the exploration of scientific and mathematical content, the connec-

1 Since 2002, Longwood has been actively involved in SENCER, and our Bay Academy builds on previously successful SENCER courses taught at LU including The Power of Water (POW), which is part of the SENCER Model Series (Fink and Parry 2007). In both 2008 and 2010, POW was linked with a statistics course for non-science majors through a semester-long research project (Fink and Lunsford 2009 and Lunsford and Fink 2010).

tions among and between science content and social and civic issues, and the infusion of these linkages into the teachers' own work with their students.

Project summary

Course structure

SOLstice was developed by a team of Longwood faculty with expertise in mathematics, science, and science education and was implemented as a four-credit summer course open to pre-service teachers for undergraduate credit and in-service middle-school teachers for graduate credit. Ten SOLstice participants, two middle-school science teachers and eight pre-service teachers, completed a series of explorations focused on "interaction between natural and social systems" (CBF 2004). In addition to honing their data-collection and analysis skills, the participants made critical linkages between the material they were learning and the middle-school science and mathematics curricula (i.e., the Virginia Standards of Learning or SOLs; VA DOE 2003 and 2009). The meta-structure of the project was a multi-week MWEE experience:

Preparation phase: The first week of the course, which participants completed through online instruction, focused on developing an understanding of the Chesapeake Bay context and on building foundational knowledge of basic statistics, chemistry, physics, and environmental science that would be applied in the action and reflection phases of the course.

Action phase: Participants completed the second week of the course in true Chesapeake Bay country at Longwood's Hull Springs Farm, a 600+-acre coastal property located on the Northern Neck of Virginia. This intense week included a series of smaller, more focused MWEE activities such as biodiversity sampling at a "living shoreline" demonstration site. Participants then moved inland to complete the third week on the Longwood University campus, still in the watershed but well out of sight of the Bay. In this third week, scientific investigations and discussions continued both in the field and in a more traditional classroom/laboratory environment with an emphasis on connecting knowledge gained to the context of teachers' own classrooms.

Reflection, analysis, and reporting phase: In the final week of the course, participants devoted energies to the completion of lesson planning activities and a course portfolio. This closing week allowed participants to reflect on all of the SOLstice activities, including the series of smaller MWEEs that also included reflection and analysis components.

Specific contexts for civic engagement and scientific inquiry

SOLstice participants explored many aspects of the Bay ecosystem, but here we highlight two specific issues to demonstrate the interdisciplinary inquiry into challenging, unresolved questions that characterized the project.

Is the menhaden fishery sustainable? SOLstice participants were challenged to seriously consider the fishing of Atlantic menhaden (*Brevoortia tyrannus*), which is argued to be one of the "most important fish in the sea" (Franklin 2007; Fig. 2A). After a Place-as-Text exploration[2] (Braid and Long 2000) in the community to learn about citizens' perspectives, participants toured Omega Protein, Inc., the largest fishmeal processing plant in the U.S. and a major employer in the area. There they heard the industry's perspective on the importance of menhaden and sustainable fishing practices. Participants then heard a different viewpoint from a Chesapeake Bay Foundation fisheries biologist and learned about menhaden populations and environmental consequences of their harvest. In an interactive session about the importance of civic engagement led by a representative from the Virginia Department of Environmental Quality, participants created a plan to address the complications of identifying stakeholders, involving the community, and building consensus for environmental policy. As a final step in this exploration, participants modeled fish populations using activities suitable for the K-12 classroom (modified from PBS 2011a and 2011b) and plotted growth and decay curves.

2 SOLstice participants engaged in a City-as-Text "walkabout," part of the Place-as-Text pedagogy described by Braid and Long (2000). For the activity, which is preceded by assigned context readings, the explorers gather at a central location to which they will return after their journeys are complete. The larger group is divided into smaller working groups that then set out with the goal to deconstruct an "uncharted territory." Groups have a clear objective: to use observational skills, pick up newspapers and other artifacts, and engage in conversation with local people in order to gain a deeper understanding of an overarching theme (e.g., the health of the Chesapeake Bay). Once the working groups return to the central location, they discuss their notes in the larger group, comparing and contrasting their experiences and developing an understanding of the text of the place they have just "read."

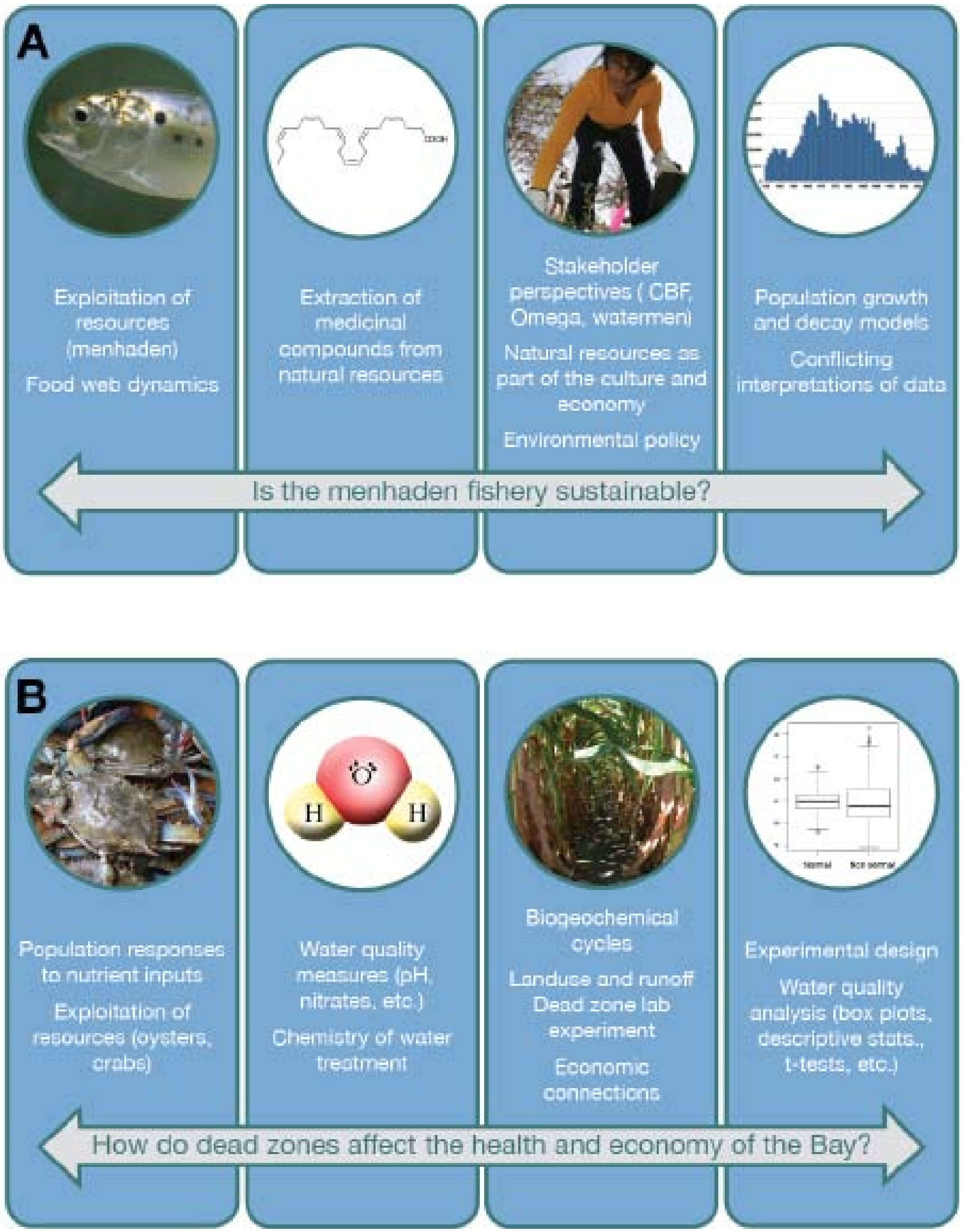

FIGURE 2. Summary of the multidisciplinary exploration of the science content and civic issues related to menhaden fishing (A) and dead zones (B) in the Chesapeake Bay.

How do dead zones affect the health and economy of the Bay? SOLstice participants also were challenged to seriously consider complex ecosystem dynamics in the context of dead zones in the Bay (Fig. 2B). At Hull Springs Farm, participants performed a battery of water-quality tests (e.g., pH, nutrient levels, dissolved oxygen, salinity, etc.) and conducted an experiment to assess the effects of nutrients on algae growth. In addition to numerical summaries of the water-quality data, participants used box plots to compare test results from two locations and to consider the inherent variation in measurements. A full-day excursion on board an historic sailing oyster boat, a skipjack, afforded participants new perspectives on the effects of nutrient pollution on oyster and crab populations, the importance of those animals in regional history and contemporary culture, and their role in the natural systems of the Bay. After a second Place-as-Text exploration in Farmville, Virginia, to learn about perspectives on the health of the Bay from citizens who live in the watershed but not near the Bay, participants toured two municipal facilities: the drinking water filtration plant and the waste water treatment plant. At both locations, participants heard from the public officials who serve as stewards of the local water resources and learned of the complex chemical and biological processes involved in treating water within the Bay's watershed.

Assessment tools

To evaluate this first iteration of SOLstice, we asked course participants to complete a suite of assessment instruments: (1) an internally developed pre- and post-course content knowledge assessment focused on key Bay issues and basic chemistry, physics, statistics, geography, and environmental science; (2) a tailored pre- and post-course version of the Student Assessment of Their Learning Gains (SALG 2011) focused on participant attitudes about science, civic engagement, and other aspects of the SOLstice experience; and (3) a post-course Chesapeake Bay Academy Evaluation (provided by VRUEC; unpublished) focused on more traditional "course evaluation" topics. SOLstice also was documented by Longwood University's Information and Instructional Technologies Services, and the resulting video is available online (http://youtu.be/gAtLWXohULI).

Project outcomes

Although the sample size for the SOLstice pilot was small (i.e., ten participants), our assessment efforts provided some interesting insights. For example, based on the pre- and post-course content assessments, we noted that SOLstice participants had incoming fundamental knowledge of statistics including the ability to recognize explanatory and response variables in an experiment and to read graphical displays of data including box plots and histograms. We did see some improvement in participants' graphical recognition of variability (i.e., standard deviation) of a quantitative variable. The pre- and post-course content knowledge assessment in chemistry focused on formulae of binary ionic compounds, basic valence electron structure, solubility of binary ionic compounds, properties of water, and common units of measure. As with the statistics assessment, we found that participants had some prior chemical knowledge. Although there was no single topic that showed significant improvement, four of the six participants who completed both the pre- and post-course content assessments showed overall improvement in their knowledge of these chemistry topics.

The Bay Academy Evaluation provided important insights into the participants' experiences, particularly related to their interest in the civic issues, and participant comments (below and later in this report) were compiled from responses to that instrument. One participant reported having:

> "a much greater appreciation for the Chesapeake Bay and my environment in general. I didn't really care for ecology much before this program, but now I think about some aspect of it every time I walk outside. I am now inspired to bring that to my future students as well."

Two other participants stated:

> "I am prepared to discuss watersheds in my classroom and stress the idea of reducing, reusing and recycling [to] decrease pollution in the world."

> "I have found my interest in caring for the health of the Bay and have the facts to back up myself when I push people to act in a more Bay-friendly way."

In completing the SALG instrument, participants reported gains in understanding how to think like a scientist; the scientific content of the course, statistics, and MWEEs;

the power of science to affect their lives; and their abilities to persist when working on hard problems.[3] Strong majorities ($\geq$ 70 percent) of participants expressed interest in adding more quantitative components to their teaching, integrating Bay issues into their classrooms, and engaging their own students in linkages between scientific and civic issues. However, we noted the absence of a gain in participants' confidence in their preparation to engage students in the linkages between scientific and civic issues as well as their enthusiasm for integrating more quantitative components into their teaching. Interestingly, participants did not appear to make gains in their habits of applying scientific knowledge and reasoning to civic actions outside the classroom.

Reflections

A primary goal of SOLstice was to provide unique learning experiences for pre- and in-service teachers, experiences focused on authentic investigations that drew on knowledge and skills from multiple disciplines. Assessment results clearly show that this goal was achieved:

> "I loved the field experiences and being able to work in the water. Getting my hands wet and testing the water was very valuable."

> "… getting out in the field and learning about the Bay made the concepts more relevant and real. Seeing perspectives from several different views, such as the menhaden issue, helped to gain a broader sense of the problem and the difficulties in resolving it."

Furthermore, we sought to facilitate the transfer of content and skills from the university environment to the K-12 classroom, and we believe this was a successful component of the project overall. The collaboration between the pre- and in-service teachers provided a unique opportunity for discussion of instructional strategies, one that participants clearly appreciated: "I also thought it was valuable to have both practicing and pre-service teachers involved in the program because we were able to learn a lot from each other." By participating in activities designed to strengthen lesson-planning skills, participants believed they could better incorporate the Bay and its complex issues into their science lessons within the framework of the Virginia SOLs for science and mathematics:

> "The most valuable aspect was that we were able to work in the field and bring it back to the classroom and discuss how we could use it in our own classroom."

> "I feel more confident designing a project that looks at the complete picture of the watershed. As a teacher of inland students, it can be more challenging to convince them of their connection. This program gave me resources and ideas to implement lesson plans that would allow the students to see the possible effects of their actions."

> "[I] am more confident in my skills in using math in the classroom and leading authentic MWEE activities for my students."

However, due to the fact that this was the first iteration of the course and course assignments had not been field tested, the richness of the MWEE construct was not fully realized in all of the participants' lesson plans. While many lesson plans contained MWEE components such as hands-on, student-centered outdoor explorations, only one of the submitted lesson plans provided for sustained student action stemming from their experience in the watershed. In future iterations of the course, the lesson planning assignment requirements will be modified to explicitly highlight ongoing scientific exploration as a key MWEE component.

Another emphasis of the course was the integration of scientific knowledge and civic engagement to result in action. Even though we studied the science within the context of the Bay, SALG data indicated that there were not strong majorities of participants saying they were in the habit of taking public action related to scientifically oriented civic issues or even discussing science-related issues informally with friends or family. This lack of integration could be a function

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3 In addition to questions on the standard SALG instrument, we also included specific questions for the SOLstice experience such as: Presently I understand (1) mathematical formulas and statistics I find in textbooks, websites, magazines and newspapers, and other media and (2) graphs and descriptive statistics for a quantitative variable (i.e., histograms, boxplots, measures of center and spread). Presently I am (1) enthusiastic about using statistics in my teaching; (2) interested in adding a more quantitative component to the teaching of my classes; (3) confident that I understand statistics well enough to use them in my teaching; (4) confident in my understanding of MWEEs; (5) interested in integrating Chesapeake Bay issues into my classroom experience; and (6) confident in my understanding of Chesapeake Bay issues.

of SOLstice's short duration, but it also may indicate some room for improvement of the "action phase" of the course. We continue to consider ways in which this key SENCER component can be strengthened, and a first step will be a focus on the "action phase" in the lesson plan assignment.

Overall, we were successful in applying the SENCER approach to our SOLstice project to provide a unique learning experience for participants as well as the faculty involved. We believe that the interdisciplinary science curriculum framed around key civic issues modeled a new approach for a classroom environment for middle-school educators. Furthermore, the opportunity for collaboration between pre- and in-service teachers provided professional enrichment and growth for both groups.

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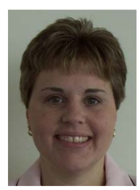

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PROJECT REPORT

The Practice of Reflection in an Integrated Pair: Math and the Environment

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Abstract

As teachers of Introduction to Algebra (MAT095) and Critical Thinking (HUP102) at LaGuardia Community College, we are well aware of our students' need to improve critical thinking and quantitative reasoning skills. With the goal of improving these skills, we paired our courses into a single learning community with a focus on the environment. This study discusses how the integration of reflective practices in classroom activities intensified our students' learning experience over six semesters. Our objective was to encourage them to assess their consumption and evaluate their responsibilities as consumers.

This report documents the evolution of our learning community "Math and the Environment" over two years, with a focus on how the practice of reflection helped students develop their number sense in the context of projects about the environment and also guided us to improve our teaching practice. First we will summarize the work done from Fall 2007 to Fall 2009 and explain our results; then we will comment on the reflection process that led to the changes we made for Spring 2010.

It is an American commonplace that many students arrive in the nation's math classes with low interest and little confidence in "doing math." Students often declare that they "hate" math (see the online I Hate Math Club, I Hate Math T-Shirts, etc.), an antipathy partially explained, perhaps, by the tendency in a traditionally taught basic math class to require rote learning of skills that may appear socially and culturally irrelevant to today's learner (Fuson 2005, 29). Educators agree that this perceived disconnect between mathematics and everyday life adversely affects student motivation (Grubb and Cox 2005, 93, 95-97) and disrupts achievement and retention

(CUNY 2006, 4-5). Committed to confronting students' negative perceptions of math, LaGuardia's Division of Academic Affairs partnered with the college's Center for Teaching and Learning to launch, in January 2007, Project Quantum Leap (PQL), a faculty development seminar to study and implement ways to improve developmental math achievement.

To narrow the "relevance" gap, PQL adopted two teaching and learning strategies. The first was the engagement of students in the exploration of "unresolved public issues," a pedagogy modeled on the Science Education for New Civic Engagement and Responsibility (SENCER) initiative which identifies compelling contexts in a real-world approach to teaching math and science. The second PQL educational strategy was the creation of new learning communities, i.e., paired courses linked by themes and projects that generate connections within and across disciplines.

In Spring 2007, we participated in PQL's first phase, the exploration of specific conditions believed to enhance math learning. Our two courses Introduction to Algebra (MAT095) and Critical Thinking (HUP102) formed an integrated pair "Math and the Environment." In addition to context and community, we emphasized reflection as vital to effective learning: Envisioned by Carol Rodgers, reflection is "the thread that makes continuity of learning possible, and ensures the progress of the individual and, ultimately, society. It is a means to essentially moral ends" (Rodgers 2002, 845). At the heart of our Fall 2007 and Spring 2008 environmental projects, the practice of reflection in the learning community furthered both of our educational goals: advancing math and critical thinking skills and clarifying connections between individual choice and the fate of the planet.

Summary of Fall 2007 – Spring 2008

In an earlier paper for *InTransit, the LaGuardia Journal on Teaching and Learning*, we reported our Fall 2007 and Spring 2008 experiences. Both semesters were framed with two projects. The first project was more personal and focused on household electricity consumption; the broader second topic was recycling at LaGuardia. Our teaching challenge was to provide our classes with opportunities to construct a clear understanding of environmentalism and of the differing perspectives surrounding it, and to develop a way to make meaning of their own experience of it. Among the learning goals, three were essential: Common to both projects was the primary requirement to justify the validity of conclusions. Second, a successful project depended upon the thoughtful collection, selection, analysis, and application of valid quantitative data. Last, the expectation was that students could perform correctly various numeric operations in the service of a reasoned argument about the environment.

We structured both projects around three activities. In the first week of Project One, our math and critical thinking learning community students gathered one week of data on the electricity consumption of three home appliances. In the second week, they reduced their individual usage by approximately half, calculated their personal savings of money and consumption, and projected the global impact of their actions on the reduction of carbon dioxide emissions. At the end of the third week, students wrote an essay that described their collection of data, analyzed the consequences of reducing their energy consumption, and reflected on the changes, if any, in their personal behaviors as consumers and the possible effects of their behaviors upon the environment.

To help students produce more informed and analytic arguments, we assigned activities to increase skill sets and knowledge. In math class, students reviewed decimals, simple averages, and unit rates within the context of activities about energy consumption. In the critical thinking sessions, students read excerpts from Al Gore's *An Inconvenient Truth*, summarized its positions, and evaluated its presentation of numerical data. Later, students were to use this information to build their own arguments about the consumption of energy. As students worked on their projects, we introduced practices of reflection in and on action. In math class, for example, students reviewed their calculations for the project; while doing so they identified computational steps and justified the results. Pairs of students discussed their calculations of electricity use and checked them for accuracy. If the validity of the answer was questioned, we put the calculations on the board for the whole class to examine. To help make sense of the numbers under discussion, we provided concrete contextual situations, calculating, for example, the total electricity consumption of a whole household. By appreciating the impossibility of a single home computer consuming in a week an amount of energy equal to the total amount of electricity consumed by a household in three months, beginning students could then understand and correct the miscalculation. Thus, after stepping back to look at the homework, students began to reflect as they calculated. In other words, by "thinking on their feet" out loud, mindfully, and in the moment, students were reflecting-in-action, a process of evaluating and modifying that is essential to the practice of quantitative reasoning (Smith 2009).

The commitment in Spring 2008 to a more intentional pedagogy also had implications in the critical thinking class. In Fall 2007, like many teachers who wish for student feedback, we had always devoted a few minutes at the beginning or the end of class to ask a general "How's it going?" question regarding progress of large projects. In those exchanges, students who felt comfortable volunteering their ideas reported out to the instructor; after they had spoken, we would move on to the "central" topic of the day.

Modified in Spring 2008, the practice of "checking in" became a guided and more deliberate exercise. Its aim was the creation of focused conversations held by a community of thinkers engaged in discussing an issue in ways that led to insights and new ways of understanding their approach to the project. For example, we turned our informal Fall 2007 "How's it going?" feedback sessions into "good conversations." Once a week, in small groups, students discussed the information they had gathered for their projects for fifteen minutes, and then each group reported out to the full class. This process ensured that students would carefully and thoughtfully talk with one another about their data collection progress. Identifying impasses and possible solutions, they created "good conversations," guided, but not controlled, by the instructors. In Schön's words, these more directed exchanges were "neither wholly predictable nor wholly unpredictable" (Schön 1998). For example, a student once hit a snag in his research of household energy consumption– his father wanted around-the-clock TV, and did not like the suggestion to turn it off in order to consume less energy. Rallying around, students urged the student to convey to his father the importance of the learning project, suggested that he take his father out to dinner, and asked if the instructor could write a letter to the father! Another time, when a few students reported falling behind on collecting data, their peers worked out an adjustment to the deadline.

A clear difference between the Fall 2007 and Spring 2008 projects was the completion of data collection by everyone in the Spring class, a result, we think, of the community of encouragement provided by our "good conversations." A combination of both reflection *in* and *on* action, these deliberate and thoughtful investments in each other's progress helped students to find solutions to difficulties. Without data, they would have given up; without "good conversations," they may not have shared their frustrations and suggestions. From teachers- giving-solutions in Fall 2007, we became coaches (Schön, 1998), encouraging our students to be active learners who rely on their knowledge and past experiences to analyze situations, make connections, and provide workable solutions not only for themselves, but also for others. These kinds of collective, reflective discussions created community, and also provided a stronger foundation for students as they wrote the final assignment for the first project. This concluding segment required the application of concepts learned in math and critical thinking classes and asked students to evaluate their findings as well as their experiences of the project and the ways the project might have motivated changed behaviors.

From these two semesters we learned that systematic inclusion of reflection in addition to careful staging and modeling of activities and more classroom time for projects, are all essential to achievement. Scores in our pre- and post-tests suggest that learners benefit from deliberate "thinking aloud" techniques combined with "stepping back" to regard completed actions. We also believe that math teaching benefits students when it is made more explicit and visible, challenging them to reflect on the ways they arrive at the identification of algorithms needed for data analysis. As indicated by their final projects, reflecting on the connection of numbers to their everyday experience enhanced skills required for the completion of their projects on energy consumption. Similarly, careful staging of activities and scaffolded projects helped students to see the relations among parts of assigned projects, resulting in improved critical thinking skills. Increased attention to modeling how to incorporate data in arguments offered students greater insight and examples that they could include in their everyday lives. Finally, devoting more class time to the practice of reflection on a common project within a compelling context encouraged students to be more active and collaborative in their learning, and more visible and accountable to each other.

Fall 2008 -Fall 2009

Because many of our students did not receive an electricity bill and others did not find the amount of money saved by reducing their electricity consumption to be significant, we switched the topic of our first project from electricity consumption to cell phone usage and recycling. While students recognized the importance of saving resources by recycling old phones, the savings were not enough to influence their behavior. In addition, in their papers they still too often relied on quantifiers ("a lot", "many") rather than numerical data, possibly an indication that they had not grasped the relevance of the data or that they could not see how the use of data would strengthen their arguments. To address these issues, we introduced two pre-activities before the first project to encourage students to see themselves as responsible agents in the future of our environment early on in the semester and to introduce them gradually to work with data by concentrating on fewer numbers. The following description of the most recent iteration of our learning community shows how our own reflection guided the way we refined our projects and developed new activities that, we hoped, would strengthen our results.

Spring 2010 - Pre-Activities

To help our students understand the relevance of numerical data and the impact of their behavior on the environment, we created a pre-activity that required the analysis of only one number. In an article on integrating quantitative literacy across the curriculum, Jane E. Miller explains that "in order to develop quantitative literacy, students need to write about numbers and the most basic skill is to report one number, which involves application of two fundamental principles that outline the essential components of a sentence or paragraph about numbers: (1) setting the context, and (2) specify the units." (Miller 2010, 334) For the first pre-activity, students determined their ecological footprint. They used a website to answer questions and at the end printed their consumption chart showing how many planets we would need if everybody behaved like them. On average every student needed at least three planets. The reflective discussion in the critical thinking class revealed that they were starting to understand their own impact on the environment for they could interpret the significance of one unit (number of planets) in its context (individual consumption). At the end of the discussion, all the students concluded that their level of consumption could not be sustained because we only have the resources of one planet, not three or four. The next step was to help them change their behavior.

For the second pre-activity, we used the "Turn the Tide-Nine Actions" program created by the Center for a New American Dream and asked students to pick one thing they were willing to give up at for at least two weeks. They could eliminate eating one beef meal, shrimp, or replace standard light bulbs with energy-efficient compact fluorescent lights in their houses. Students were put into groups according to their choice, followed the given calculation steps to evaluate the resources saved, and reported their results to the rest of the class. In this case, the units were shrimp, beef, or light bulbs and the context was again individual consumption. When they saw the potential impact of this minimal change, 19 out 21 students committed to replacing at least two beef meals or not eat shrimp for two weeks.

Here are some of their comments: "I will actually reduce my footprint because 8 people will be fed by me reducing beef." For shrimp, students wrote: "I will and I can reduce my footprint. Yes I can reduce it because it's worth it. I'm saving 132 pounds of sea life." "I believe that actually reducing my footprint would make a difference. I really care what happens to the environment."

Eight of nine students reported in the end of semester reflection that they continued after the two-week period. Also, those who had decided to replace light bulbs reported changing more than the four they had committed to. These two pre-activities helped us show our students that any change in behavior is significant for the environment. We believe that the combination oe reporting and contextualizingfonly one or two numbers with the in-class guided reflective discussions made it easier for the students to analyze data and connect it to their own experience.

Spring 2010 – Project #1

Building on students' improved number sense, we introduced the first project, "Let's Talk about Cell Phones," by showing "The Secret Life of Cell Phones," a data-driven video about the waste of resources generated by not recycling cell phones. Prepared questions helped students listen for specific information; afterwards, in the critical thinking class, students recalled data and reflected on the implications for them as cell phones users. In the math class, with the data from the video and class survey about peer cell phone habits, students evaluated the resources saved by recycling old phones.

Analysis of Student Work Project #1

We created a prompt that would encourage students to reflect on their connection to the environment.

TABLE 1. Reflection Paper Evaluation Rubric.

Indicator	Level 1	Level 2	Level 3	Level 4	Level 5
Presentation of argument	Presents no argument	Presents an argument	Presents an argument	Presents a detailed argument	Presents a fully developed and detailed argument
Use of numerical data in support of argument	Does not include numerical data	Does not include numerical data	Includes numerical data, but data does not support the argument	Supports the argument with numerical data, but the data is miscalculated	Supports the argument with numerical data that is appropriate and accurate
Description of impact of experiment on student's life	Does not describe impact of experiment	Does not describe impact of experiment	Describes impact of experiment	Describes impact of experiment	Describes impact of experiment in detail

Please reflect on your behavior regarding cell phones. You may use the questions below as guidelines.

1. Based on this project, what have you learned about cell phone usage? What is the most shocking piece of information you have discovered and why do you think it is shocking?

2. Based on the potential for cell phone reuse and recycling, what do you think we can do to encourage people to reuse and recycle their cell phones? In your opinion, how necessary is it?

3. How has this study affected your own behavior as a consumer of cell phones? With what you know now, would you consider changing the way you are "consuming" cell phones? What would you change and why?

4. What we have discovered about cell phones is also true for computers and many things we consume every day. In your opinion, what is our responsibility as consumers toward the environment and the rest of the world?

To evaluate our students' work, we used the rubric (Table 1) we developed In Spring 2008 to measure the extent to which students incorporated numerical data to support the argument in their reflection papers.

Out of fourteen students, eight turned reflections. Three papers were Level Five, three papers Level Four and two papers were Level Three. There were no papers in Level One and Level Two. In Spring 2008, for the first project, which did not include the pre-activities, out of the twenty papers we collected, two were Level One and nine were Level Two. The fact that the project with the pre-activities did not have papers in Level One and Two seems to indicate that the pre-activities exposed students to data earlier on in the semester and lead them to use more data more accurately in their reflection papers for the first project.

Spring 2010 – Project #2

To continue with the idea of slowly increasing the quantity of numbers students would work with, we redesigned Project #2 and limited its scope. Rather than recycling at LaGuardia (Spring 2008) or recycling clothes (Fall 2008-Fall 2009), which required research that was sometimes overwhelming for students, we aimed at increasing consumer responsibility and at reinforcing the use of data by focusing on their consumption of plastic cans and bottles. For one week, students collected information on the household use of plastic bags and bottles. In the following week, students reduced their consumption as much as possible, collected the data, and kept a journal about the process. During the math class at the end of that week, they calculated the savings in oil and electricity, and reflected on the impact of their change of behavior. By adding only two other units of comparison (oil and electricity), we helped our students with their number sense without overwhelming them with new data. Just as we staged our projects, we included reflection questions throughout the data analysis. "Let's Stop and Think" questions accompanied each calculation with the objective students would draw on these mini-conclusions to construct a more developed end of term essay.

Analysis of Student Work for Project#2

"Let's Stop and Think" prompt: Is the amount of energy/oil saved worth changing your consumption of plastic bags/ bottles? Explain your answer; "yes" or "no" is not a complete answer.

Project One and Project Two results were similar: Out of fourteen papers, five were Level Five, four were Level Four, and, and five were Level Three. Given that the students performed the calculations independently, we were not surprised to find more papers at Level Four, where students develop an argument, but support it with wrong data. Yet the end of the semester reflection papers, which included questions for the pre-activity and for the two projects, did not show an increase in the use of data despite the addition of the "let's stop and think" questions. Overall, out of nine students, four included data for all three projects; one included data for two of the projects, three included data for one project and only one did not include data at all.

Conclusion

Adding pre-activities that included in-class reflective discussions and reflection papers made the first project more meaningful to students and helped them develop their number sense by introducing them more gradually to data analysis. To measure the impact of these projects on student critical thinking skills, we added an "explain" component to the multiple choice pre and post test given in the math class (Ennis 1993, 181). For each answer students gave, they had to explain their choice. While the increase in the number of correct answers is small, the "explain" part is very promising. In the pre-test only two students out of fourteen gave explanations for six or more questions, but in the post-test, five students gave explanations for more than seven answers. Not only have students improved their number sense, they are also better at presenting mathematical arguments. For the six semesters we taught our pair, the on-going practice of reflection gave us a frame to examine, rethink, and hopefully improve our student quantitative literacy and critical thinking skills as well as our teaching.

The benefits of teaching in a learning community, especially with basic skills, are valuable. The second year, we made every effort to attend each other's class. We did not co-teach but we participated in activities with the students. This helped us create a real community and provided extra support for the students and the professors. We plan on teaching another pair of classes with Introduction to Algebra and Small Group Communication. The math class will be organized around modules. Students will advance in the course at their own pace by working together in small groups. In the communication class, the students will learn how to work in groups efficiently to make the most of the modular approach. In both courses, we will continue to use reflection to assess student work and progress. We strongly believe that a thematic approach combined with the practice of reflection at the center of a pair of classes including ~~with~~ Introduction to Algebra will encourage students to succeed and persist in their studies.

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RESEARCH ARTICLE

Engaging Within Time Limits:
An Integrated Approach for Elementary Science

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Abstract
Insufficient time is devoted to learning science in elementary schools. This study engaged elementary preservice teachers in a curriculum that integrated children's literature with inquiry-based science. The study sought preservice teachers' perceptions about the value of the curriculum and the impact it had on their knowledge and interest relative to science and providing science instruction to elementary students. Features deemed important were accommodating a range of learners, reading stories, fun activities, and learning about the environment. Findings provide strong evidence that exposure to the curriculum changed preservice teachers' perceptions from "dislike science" to "now enjoy teaching it," and accordingly, support for initiating science methods courses through curricula with these features.

Engaging Within Time Limits: An Integrated Approach for Elementary Science
With the continued restraints on elementary level science instruction due to accreditation and assessment requirements, science curricula needs to be flexible while still emphasizing high quality 21st Century learning (Center for Educational Policy, 2008). Such curricula needs to accommodate instruction from other disciplines and target skills, principles, and standards that are shared with science; inquiry and related process skills should be high priority (Henderson, Hatheway, Gardiner, & Zarlengo, 2006; National Council of Teachers of English, 1996; National Council on Teachers of Mathematics, 2000; National Research Council [NRC], 1996). *A Framework for Science Education* (NRC, 2012) attempts to clarify what is meant by scientific inquiry—it is not an isolated set of skills, rather it requires the coordination of scientific knowledge and skills in the form of scientific practices. This is especially critical for elementary age children because first and second grade instruction sets the ground work for later success in school (Eshach, 2006; Harvard-Smithsonian Center for Astrophysics, 1997).

Engaging student interest and their participation in the process of investigation are paramount to the promotion of science learning (Minner, Levy, & Century, 2010). The availability of the Elementary GLOBE (EG) curriculum represents one recent effort to engage K-4 students in hands-on science learning in this time restrained teaching environment (Hatheway, Gardiner, Henderson, & Zarlengo, 2006). EG provides opportunities for children to utilize manipulatives in fun and adaptable activities that promote science inquiry in the context of learning earth science concepts, and the curriculum is unique in that it combines earth system science with literacy (Henderson et al., 2006). The earth systems focus facilitates environmental literacy at an early age, which is a growing concern of global dimensions (Lubchencho, 1998; Chepesiuk, 2007). An earth systems focus coupled with inquiry also provides opportunity to immerse children in the essence of science, which is the attempt by humans to understand the natural world (Bass, Carin & Contant, 2009). Additionally, EG responds to the concerns of Jerome Bruner (1999), who believed that teachers need to provide numerous materials for exploration, so students can represent their new knowledge through actions, drawings, or words (Howe & Jones, 1993). Preservice teachers' confidence, motivation and dispositions toward the teaching of science are important in realizing more science instruction at the elementary level (Watters & Ginns, 2000). Exposing preservice teachers to "fun" science learning experiences may increase their confidence and lead to greater provision of science instruction.

Purpose

This study examines elementary preservice teachers' perceptions (via a reflective assignment) about their experience with EG in a university science methods course. The principal research question was: What do preservice teachers perceive as the salient features of EG relative to using this resource in their future teaching?

Conceptual Framework

Edwards (1997) and the National Science Teacher Association (1998) promoted engaging students in the application of thinking skills for inquiry-based instruction. The processes of inquiry/science process skills (e.g., observing, measuring, predicting, and experimenting), when coupled with science content, become "scientific practices" that foster meaningful understanding in students as well as advances in scientific knowledge by researchers (Llewellyn, 2002; NRC, 2012). For students, the teacher becomes the facilitator for engaging in scientific practices, guiding them in developing context for solving problems related to the real world. This builds on connections made between experiences, permitting the linkage of knowledge, skills, and attitudes.

Paramount Role of Inquiry and Practices

An emphasis in preservice science teacher education for at least the past decade has been on the pedagogy of scientific inquiry (NRC, 1996, 2001). "Inquiry refers to the abilities students should develop to be able to design and conduct scientific investigation, and the understanding they should gain about the nature of scientific explanation" (Lind, 2005, p. 6). In grades K-4, students obtain competency in inquiry by achieving the following benchmarks: "(1) ask questions which can be answered with scientific knowledge; (2) plan and conduct a simple investigation; (3) employ simple equipment to gather data; (4) use data to build a reasonable explanation; and (5) communicate explanations based on the investigation" (NRC, 1996, p. 122). A Framework for Science Education (NRC, 2012) broadens the focus of scientific inquiry to "scientific practices," and emphasizes that young learners need experiences that develop their capabilities to observe, measure, and record (including drawing) as well as opportunities to communicate.

How do we best teach inquiry-based science and more broadly develop in students' scientific practices, given the time restraints of mandated assessments created by preparing and executing federal mandated testing (Posnick-Goodwin, 2006)? This is a daunting task, given that students should have opportunities to observe, pose and investigate questions, analyze and represent data, and communicate findings (Lind, 2005; Martin, 2003). The teaching of inquiry-based science to young learners is likely best accomplished through science curricula that incorporate other disciplines, especially reading/language arts and mathematics. This approach affords more time to develop and hone inquiry skills, such as making inferences from reading and/or observations and communicating via the construction of graphs (Bass, Content, & Carin, 2009). It also provides the opportunity to continually make connections between learning experiences and from one context to another. A quality level of engagement ushers forth from successful immersion with inquiry methodology.

Study Design and Methodology

While considering the aforementioned aspects of elementary science, a study was designed to examine elementary preservice teacher perceptions about the value/utility of the Elementary GLOBE (EG) curriculum as a resource to provide inquiry-based science learning opportunities for children (Henderson et al., 2006). The study took place at a land grant institution in the Mid-Atlantic region of the United States and was approved by the university's Office on Research Compliance. The design used phenomenological data (Patton, 2002) in the form of reflections about an EG experience (orientation to and hands-on activities) completed by preservice teachers near the beginning of the elementary science methods course in which they were enrolled. EG consists of 5 modules— seasons (phenology), soil, water, clouds, and earth as a system—to develop earth systems literacy. Each module includes a storybook featuring "the GLOBE Kids" exploring local environments and is rich in other applications to literacy (e.g., building vocabulary, journaling). EG provides a checklist of inquiry process skills (Helm, 2008) that elementary students utilize as they engage in a variety of learning activities, many in the natural (outdoor) environment. Further description of EG is provided by Henderson et al. (2006) and on-line free at (http://globe.gov/web/elementary-globe/documents). A through overview of curriculum is at http://www.globe.gov/web/elementary-globe/overview. Additionally, the developers of EG created *Ducks in the Flow* storybook which highlights changes seen in the oceans as the planet changes. It can be retrieved at http://www.windows2universe.org/teacher_resources/ocean_education/currents_main.html.

These resources provide features that build teachers' understandings of earth system science. They build civic involvement when students learn about issues impacting them at school and in doing so learn about ways they can become involved with projects to advance the discussion.

Participants

Participants were a convenience sample of 60 elementary preservice teachers (PT): 40 were enrolled across two sections of an undergraduate science methods course (Fall, 2009) and 20 across two sections of a graduate, initial certification science methods course (Summer, 2010). These science methods courses were very similar in scope and focused especially on inquiry-based learning, science process skills, and the 5E learning model (Bybee & Landes, 1990) as a part of elementary science instruction.

Data Collection

The reflections data were collected from all 60 PT soon after they had completed the EG experience. The reflections were part of a normal class assignment in which PT were asked to reflect on EG as follows:

- What are your thoughts about the value of Elementary GLOBE as part of the elementary school curriculum?
- If you were to use Elementary GLOBE for instruction, how would you implement it in your classroom? (For example, what modifications might you make based on your student's interests, prior knowledge, learning needs, etc.)
- What impact has this exposure to Elementary GLOBE had on your knowledge, interests, and/or attitudes about science and science education for children? (Please explain)

Data Analysis

Inductive analysis was applied to the reflective assignments. Specifically, open coding was employed, which lead to the formation of categories and finally themes (Patton, 2002).

To verify the categories, the reflections were read a second time, and there were no new emerging categories. The data was examined multiple times and the findings were the same.

Findings and Discussion

PT described in some detail their answers to questions 1, 2, and 3, and identified several areas of significance in regards to teaching elementary science. Table 1 lists words that surfaced repeatedly in their reflections.

The broader categories from a condensation of Table 1 were ease, fun, environment, integrated, reading, and adapted. Seventy-eight percent (47 out of 60) of PT found the curriculum to be "fun." This category surfaced throughout the PT reflections. Sixty-five percent found the curriculum to

TABLE 1. Number of PT (n=60) Stating Word in Response to Questions in Reflective Assignment

Words	All Three Questions	Q 1 (value)[a]	Q 2 (implementation)	Q3 (Impact)
Fun (excited, enjoy)	47	27	6	35
Adapted (accommodate, bilingual)	39	4	35	2
Reading (reading theatre)	34	14	12	8
Integrate (cross curricular)	33	16	11	6
Hands on	28	18	8	5
Stories (storybook)	14	11	5	1
Ease (easy, simple, convenient)	14	8	3	3
Global (world, earth)	12	9	2	1
Outside (explored/natural world)	11	6	1	4
Engage (engaging)	10	5	2	3
Inquiry	8	5	2	3
Time	5	4	5	4
Environment (go green)	4	2	3	1

[a] Abbreviation of question: See Methods for full iteration of each of the three questions.

be easily adaptable (e.g., bilingual instruction, special needs) for use with teaching. Fifty-seven percent of PT liked the reading format found in EG. This included opportunities to use a "reading theatre" and for vocabulary development. The engaging stories associated with the curriculum permitted integration of subjects like math and social studies. Fifty-five percent of PT identified integration of science with other subjects as a positive reason to use EG. Only 13 percent (8 of 60 PT) mentioned teaching science through inquiry methodology. This is of concern, given the importance of inquiry in science instruction (e.g., NRC, 1996) and EG.

Emerging Themes

Four themes emerged from the reflections assignment. The theme of concern for the environment from a global perspective vies for being the most important found in the reflections. This is supported in the literature: "Today's children will one day be responsible for making decisions that will shape the future health of the environment…they need a sound environmental education as a foundation upon which to make those decisions" (Chepesiuk, 2007, quoting Deborah Miller).

Three additional themes emerged from the reflections assignment and are listed with concern for environment as follows:

- PT believed fun is a major motivator for teaching elementary science. 'Fun' occurred as a theme in the highest frequency in PT reflections and also emerged from interviews conducted separately with a small subset of PT, which indicates internal homogeneity. This finding supports substantive significance and indicates consensual validation (Patton, 2002).
- The integration of reading and stories is a favorable reason to use EG for science instruction. This includes the integration of social studies and math. The PT reflections showed convergence on this theme especially with 55 percent and 57 percent of PT including the terms reading and integration, respectively, in their reflections. (Table 1).
- PT expressed a dislike for science but now enjoyed teaching the subject with EG. This was highlighted with the findings from the reflections where 68 percent (41 of 60) PT indicated their view of science had changed. This shows substantive agreement among the PT data (Patton, 2002).
- Concern for the environment from a global perspective.

PT believed fun is a major motivator for teaching science. Fun is identified as a motivator for learning and coincides with many other frequently occurring words related to science investigation by students outdoors. "However, by reading the [EG] implementation guide and working on the modules, I discovered how much fun science can be for children" (Sally—fictitious names are employed for all excerpts). PT frequently used the word "fun" in describing how the curriculum would affect their science teaching, as conveyed in excerpts shown subsequently to support other themes.

PT liked EG for integration of reading and stories related to the storybooks component of this curriculum. Since the EG storybooks correlate with a science exploration, this has an impact on students' reading, comprehension, and literacy development. PT liked the EG curriculum due to its ease of integration with language arts and math in elementary school. Over one-half thought the curriculum had value in instruction for reading, which is a core subject used in building foundation for learning. Susan reflected about this ability to integrate:

Allowing student[s] to be exposed to colorful picture[s] that are exciting to read and relatable to students is a really great feature that the program has to offer. Also, this program provides teachers with the ability to create simple labs within the classroom that helps students explore the wonderful nature of science and realize learning can be fun.

PT expressed a dislike for science but now enjoyed teaching the subject with EG. Many PT expressed a new found enjoyment of science teaching after having been exposed to EG. Mary related this to her previous science experiences:

I feel that being exposed to Elementary GLOBE has helped change my outlook on science. To be completely honest, science was never a favorite subject of mine but that was just due to the fact it was always presented to me in a boring manner. With a program set up such as Elementary GLOBE I feel that it makes science fun, exciting, and adventurous for both teachers and students which is a wonderful thing!

Stephanie also recalled the past and was explicit about the potential of EG to bring about positive dispositions toward science:

In the past my experience with science has never been a positive. I can remember back when I was in elementary school and science to me was a mess of confusing term[s] and complicated processes that didn't make sense to me. I feel that if my science classes back then used tools like Elementary GLOBE I might not have felt so negatively towards the subject.

The science education literature reveals that elementary teachers often have had negative or few science experiences, and as such, are in need of positive encounters with the discipline (Gunning & Mensah, 2011; Watters & Ginns, 2000). According to PT participating in this study, engagement with EG provides one such experience.

PT liked the accommodative capability of EG for use in their future classrooms. This theme showed up with the second highest frequency among the reflections. This is noteworthy when considering how to adjust lesson plans for student ability. Since instruction time is a major factor on deciding what to teach, curriculum should be easily implemented according to student needs. Molly conveyed the scope of this issue and elaborated on her plans to address it:

As we all know, there are many types of students in [the] classroom. There are gifted, ESL, LD, ADHA, and BD students. For these specific students, accommodations need to be made. For ESL students, I plan on having [the] Spanish version available for them to have as well as an English version...For gifted…[If] it [curriculum] requires them to write one sentence, gifted students will need to write three.

The process of adapting science lessons for special needs students' needs to be relatively seamless, given the limited time that most elementary teachers have to do this. Jenny described how EG would facilitate this:

I have to be sensitive to the needs of students that are involved in special education. ..I think it would be relatively easy to implement Elementary GLOBE materials into the curriculum because picture books, hands-on activities, and text to real life connections make learning meaningful and help make the materials easy to understand.

Jaclyn perceived that EG "accommodated the different learning styles…visual learners are able to look at the pictures in the stories…touch/experience learners are able to explore the different topic[s] by doing hands-on." Importantly, the experience with EG enabled PT to see how science instruction easily can be differentiated to meet a variety of student's needs.

Conclusions

The themes emerging from this study reveal characteristics that are desirable in science curricula in order to realize more science instruction in the elementary classroom. These characteristics are making learning fun, integrating learning with other disciplines, accommodating special needs learners, and incorporating the outdoors/environmental aspects. From the perspective of the participants (elementary PT) in this study, EG manifests all of these characteristics. Accordingly, the findings of this study suggests that a "best practice" in elementary science methods is to introduce early in the course a curriculum like EG as a model for science instruction. Although seemingly trite, the perception by PT that it is "fun" to learn through this curriculum is of considerable importance (Kayla & Lundeen, 2010). PT gave ample evidence that these "fun" experiences served to counter the negative attitude towards science that many PT bring to the elementary methods classroom (Gunning & Mensah, 2011). A recent study found that inservice elementary teachers' attitudes towards science instruction also changed when using EG (High, 2012). These changes showed in the PT excitement to teach science, corroboration with colleagues on science teaching, and motivation to make science fun in the classroom.

Equally important is the realization by PT that science learning easily can dovetail with literacy/reading instruction (Henderson et al., 2006). This attribute enables PT to connect science learning to the multiple methods courses that they take targeting literacy and reading. Additionally, given the increased time being devoted to reading/language arts and the national mandates for achieving competence in reading, PT come to realize that there is more room in the day for science instruction when it provides the context for reading and other components of literacy (CEP, 2007, 2008). This may lessen the obstacle for teachers of insufficient time to teach science (Plevyak, 2007). A curriculum such as EG can be implemented within the time limitations of present scheduling restraints of elementary teachers. Future research should address further how to counter the time limitations for science instruction imposed by the present day mandated assessment tests. Until then, curricula like EG can assuage the lack of time to teach science lessons in the "time starved" elementary school curriculum.

Accommodation to meet the needs of all learners—be they special needs students or students with different learning styles—was recognized by PT as an important responsibility in the teaching profession. They perceived that EG would help them facilitate this process, which can be a tremendous challenge depending on the diversity of one's class. Helping all students to be successful learners through differentiating instruction and other processes is a primary goal of schooling.

Richard Louv's Last Child in the Woods (2006) has brought to public attention the growing "nature deficit disorder" in today's youth. Given that science is our attempt to make sense of the natural world, it is logical that science instruction should devote more time to earth science curricula and outdoor "environmental" experiences. Environmental literacy is an important federal endeavor as evidenced by numerous and current funding opportunities, most notably by the National Oceanographic and Atmospheric Administration (http://www.fundee.org/pdf/DirectoryofEEFederalGrants.pdf). EG is a model for age-related inquiry activities in or about the outdoor environment. Accordingly, EG provides teachers with a tool to meet the growing need for environmental literacy and through a hands-on inquiry approach.

This study and others suggest that PT awareness of the importance of inquiry remains a challenge (Bryan & Abell, 1999; Edwards, 1997). It was surprising that few (8 of 60) PT in this study listed inquiry as a factor in teaching elementary science, given that EG explicitly and extensively incorporates inquiry skills. In part, this may be due to the fact that the reflection questions did not explicitly address inquiry. Given the national emphasis on inquiry and that the process cuts across disciplines, PT need to recognize its importance, gain the respective pedagogical content knowledge, and be able to include in the curriculum ample inquiry experiences for children (Forbes & Davis, 2010; Minner, Levy, & Century, 2010; NRC, 1996). This takes on additional importance in light of recent challenges articulated by the California Council on Science and Technology (2010): Many elementary teachers in California report that they are not able to include any inquiry-based science in their curriculum. Future research should examine different instructional approaches with PT towards increasing their recognition of the importance and adoption of inquiry-based methods for teaching science. Towards this end and as a logical extension of EG, the authors of this study are integrating garden-based learning with the preservice methods courses and connected practicum experiences in professional development schools (High, 2012; Rye, Selmer, Pennington, Vanhorn, Fox, & Kane, 2012).

About the Authors

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