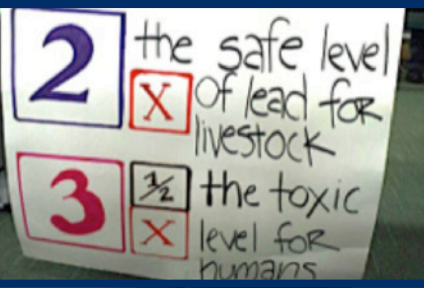


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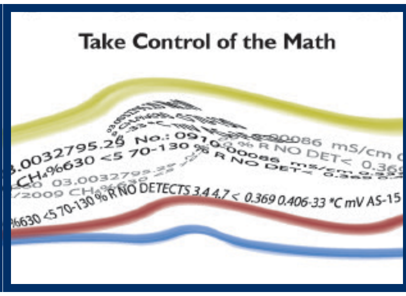

About the Journal

Science Education and Civic Engagement: An International Journal is an online, peer-reviewed journal. It publishes articles that examine how to use important civic issues as a context to engage students, stimulate their interest, and promote their success in mathematics and science. By exploring civic questions, we seek to empower students to become active participants in their learning, as well as engaged members of their communities. The journal publishes the following types of articles:

- *Book & Media Reports*
- *Point of View*
- *Project Reports*
- *Research*
- *Review*
- *Science Education & Public Policy*
- *Teaching & Learning*

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From the Editors

This issue of *Science Education and Civic Engagement: An International Journal* contains several articles that focus on community partnerships and the educational benefits that arise for all participants.

Naomi Delaloye (University of Montana) and her co-authors describe a science education outreach program for middle and high school students that focuses on outdoor and indoor air pollutants. This theme provides an opportunity for teachers and students to engage in authentic, inquiry-based scientific investigations throughout the school year. Lesson plans are integrated into the school curriculum and aligned with local and national standards, including the Next Generation Science Standards.

Colleen Lopez (California State University, San Marcos) and her co-authors provide an account of a service learning project that enriches the science curriculum for local K-5 students. Teams of STEM majors at the university participated in a carefully structured curriculum development program, followed by a presentation of their lesson in a K-5 classroom. Over three years, this large-scale outreach initiative has transformed the scientific knowledge and attitudes of elementary school students.

Martha Merson (Technical Education Research Centers) and her co-authors describe the *Statistics for Action* project, which aims to provide the public with intelligible quantitative information about environmental hazards. Participants developed effective strategies for communicating numerical data in a way that could be understood and discussed by members of the community.

Jenny Dauer and *Cory Forbes* (University of Nebraska-Lincoln) examine how students make decisions about complex issues with both a scientific and social dimension called "socioscientific issues." The authors use these issues as a framework for developing students' scientific literacy in a large-enrollment course of approximately 500 students each year. Their project report shows how the course design prompts students to shift their thinking from absolutist opinions to more nuanced reasoning based on scientific evidence.

*Nasrin Mirsaleh-Koha*n and *Cynthia Maguire* (Texas Woman's University) describe how using a photo-book in their classes enables students to make connections between scientific concepts and their real-world experiences. In addition to submitting their own photographs, students wrote reflective commentaries on contributions from other members of the class. This teaching strategy has been implemented in several courses, and can be easily adjusted to accommodate classes of various sizes.

Kenneth M. Voglesonger (Northeastern Illinois University) and his coauthors created Muddy Waters, a first-year experience in an urban university that connects students to local environmental geology. The project-based curriculum enables students to collect authentic scientific data and examine the geological factors that affect drinking water supplies and flooding risk. The course also provides students with skills that enhance their academic success, such as time management and collaborative learning.

We wish to thank all the authors for sharing their engaging work with the readers of this journal.

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

PROJECT REPORT

Making Decisions about Complex Socioscientific Issues: A Multidisciplinary Science Course

Jenny Dauer
University of Nebraska-Lincoln

Cory Forbes
University of Nebraska-Lincoln

Abstract

A new interdisciplinary, introductory, undergraduate science course was designed to help students develop science literacy, defined as decision-making about challenging, science-based issues in social contexts. The course, required of all undergraduates in the College of Agricultural Sciences and Natural Resources at the University of Nebraska-Lincoln (UNL) and reaching approximately five hundred students each year, affords a structured classroom setting in which students practice making decisions about local, regional, and global issues at the intersection of science and society (e.g., economics, politics, and values ethics). The goal of this paper is to provide theoretical grounding and rationale for the course, to describe key features intended to support students' developing decision-making competencies, and to outline initial observations and reflections that inform longer-term research and development efforts associated with the course.

Introduction

The idea of "science literacy" lies at the heart of reform efforts in science, technology, engineering, and mathematics (STEM) education reform and serves as a primary rationale and global vision for the impact of systemic K-16 science education on civics and society. The National Research Council (1996, 21) has defined science literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity." Science education researchers have historically viewed science literacy as the set of STEM knowledge, orientations, and competencies that enable individuals to engage effectively with a multitude of challenging, science-based issues at the intersection of science and society, often referred to as socioscientific issues (SSIs) (Feinstein 2011; Kolsto 2001a; Sadler 2004; Sadler and Zeidler 2009). However, there remains a multitude of perspectives on *how* science literacy should be cultivated in both formal and informal learning environments. Many emphasize the need for individuals to simply know more science. However, as Mullen and Roth state, "You can know all you need to know about your world and still not know what to do, which choices to make" (2002, 1). A key distinction must therefore be made between supporting students simply to learn science and supporting students to *learn to use science* (Bybee et al. 2009). To truly cultivate science literacy at a societal level, we must transcend the teaching of pre-determined bodies of disciplinary STEM knowledge. Instead, individuals must be actively supported to learn to leverage and employ this scientific knowledge; negotiate its intersection with social, cultural, and economic values; concretely identify relevant problems; evaluate real options for action; and move towards fundamentally different methods of accomplishing their goals. Science literacy, then, must fundamentally foreground decision-making about SSIs and how individuals mobilize STEM to support this process.

The need to emphasize decision-making as part of science education has long been noted by the scientific community, such as the Association for the Advancement of Science (Rutherford and Ahlgren 1989) and the National Research Council (1996), as well as by science educators themselves (Aikenhead 1985; Kolsto, 2006; Millar and Osborne 1998; Zeidler et al. 2005). As tomorrow's voters, workers, policymakers, and consumers, postsecondary students—both STEM majors and non-majors—must be prepared to examine complex SSIs and make socially responsible, STEM-informed decisions about them. Institutions of higher education have a responsibility to prepare students for all facets of life, help them master "Twenty-First Century Skills," such as integrating knowledge and decision-making, and contribute to lifelong development of science literacy. Postsecondary science learning environments can afford undergraduate students a highly effective, interdisciplinary, and collaborative experience with the STEM dimensions of the lived world. These experiences, which exhibit key elements of effective undergraduate STEM teaching and learning (National Research Council 2015), are often grounded in innovative partnerships between faculty from STEM disciplines, education, and the social and behavioral sciences.

We firmly believe that enhanced decision-making capacity can be actively taught and supported. Making high-quality decisions about SSIs involves being deliberate, rational, and paying attention to uncertainties (Kahneman 2011). However, this is a difficult process, as individuals are prone to snap judgments that are quick, irrational, and subject to error. A limited body of research on undergraduate students' decision-making about SSIs illustrates challenges they experience. These challenges include struggling to evaluate the advantages and disadvantages of alternative outcomes and to reflect on their choices (Grace 2009), being prone to place more emphasis on values than on scientific information when considering alternative solutions (Grace and Ratcliffe 2002; Sadler 2004) and having difficulty integrating knowledge gained in science with real-world problems (Kolsto 2006; 2001b). However, insights from the decision sciences provide insight into how to scaffold and support students' learning specifically to engage in more sophisticated decision-making over time, for example, by making students aware of the common psychological traps that can bias decisions, as well as teaching specific skills for incorporating both technical information and personal values into decision-making (Arvai et al. 2004). As science instructors, we are uniquely positioned to help students slow down, reason through a problem, apply scientific evidence, and thoroughly examine choices (Covitt et al. 2013).

Science Literacy 101: Science and Decision-Making for a Complex World

We have designed a unique multidisciplinary undergraduate course entitled SCIL (Science Literacy) 101: *Science and Decision-Making for a Complex World*. The course is an introductory course required for all majors in the College of Agricultural Sciences and Natural Resources (CASNR) at UNL. During any given semester, the students include those from a range of STEM majors (two-thirds of the students) and non-majors (one-third). Most of the students (eighty to ninety percent) are first-year students. The course has been recently overhauled and redesigned with the primary objective of supporting students' science-informed decision-making. Throughout the course, students practice making science-informed decisions about topics such as water, energy resources, conservation of biodiversity, and food production using creative decision-making tools whose development was informed by theory and research from STEM education and the decision sciences (Arvai et al. 2004; Feinstein et al. 2013; Kolsto 2001a; Ratcliffe 1997).

Course structure

The course is organized around (a) a lecture component with approximately 120 students per lecture section who meet for two seventy-five-minute blocks each week for the first ten weeks of the semester, and (b) associated recitation sections that meet each week for fifty minutes for fifteen weeks. During the last five weeks of the semester the lecture does not meet so students can focus on their final projects in their small groups associated with each recitation. Each lecture lesson is characterized by innovative active learning teaching strategies including think-pair-share, in-depth learning activities, large and small group discussion, and clicker questions (Eddy and Hogan 2014; Freeman et al. 2014; Haak et al. 2011; Lane and Harris 2015), peer instruction in assigned permanent groups of three or four (Cortright et al. 2005; Crouch and Mazur 2001), and the use of a Learning Assistant model. We used a Learning Assistant model for conceptual learning improvement (Smith 2009) and to reduce the student-to-instructor ratio and develop a more connected classroom community. A graduate student Learning Assistant is assigned to each recitation section, leading small-group discussions and assisting the primary instructor in the lecture class meetings.

SSI-based decision-making assignments

The course is designed around two-week modules focusing on four salient SSIs to students living in Nebraska: (1) Should we hunt mountain lions in Nebraska? (2) Should we further restrict the amount of water used for agriculture in Nebraska? (3) Should we use corn ethanol for a transportation fuel? and (4) Should you eat organic food? For each of these SSIs, students are asked to investigate the economic, environmental, ethical, social, and cultural aspects relevant to the problem and to develop opinions about each SSI based on their values and scientific information. During each unit, the students have two main points of individual assessment. The first assessment asks students to evaluate claims and evidence related to each issue in both popular media articles and primary research journal articles. Then the students are asked what information they still need about the issue in order to form an opinion or make a decision. The students then seek this information and evaluate whether or not they have been successful in finding trustworthy information that answers their question. The second assessment asks students to follow a seven-step decision-making process based on previous work (Ratcliffe 1997) to explain what they think could be done to solve the problem while integrating scientific information that they have researched. The decision-making steps are as follows:

1. Define the Problem: What is the crux of the problem as you see it?
2. Options: What are the options? (Discuss and list the possible solutions to the problem.)
3. Criteria: How are you going to choose between these options? (Discuss important considerations and what is valued in an outcome.)
4. Information: Do you have enough information about each option? What scientific evidence is involved in this problem? What additional information do you need to help you make the decision?
5. Advantages/Disadvantages: Discuss each option weighed against the criteria. What are the tradeoffs of each option?
6. Choice: Which option do you choose?
7. Review: What do you think of the decision you have made? How could you improve the way you made the decision?

This framework is based on a heuristic developed by Ratcliffe (1997) to address areas of students' difficulty in decision-making. We have found it to be a useful tool to support students while decision-making about SSIs because of its clarity, simplicity, and wide applicability to issues. This heuristic for decision-making has been used in subsequent studies at a high school level with conservation biology topics (Grace 2009; Grace and Ratcliffe 2002; Lee and Grace 2010). Student responses to these two major assessments are graded via a rubric that primarily evaluates them on the basis of comprehensiveness, sound reasoning, and clear and compelling explanations or arguments.

Data collection

We collected data with the purpose of giving a general description of broad patterns in students' reasoning before and after their class. Before instruction and after instruction, the students were asked to respond to "what we should do?" and "why should we do it/not do it?" about the four SSIs (for full question texts see Appendix A). In order to shorten our pre/post testing format, a subset of randomly selected students from two lecture sections taught by the same instructor received any given question. Individuals received identical questions pre and post. In a previous iteration of the course taught in Fall 2014 without the decision-making heuristic, we observed that students tended toward extreme "pro" or "con" views around each issue (Dauer and Forbes 2015). We coded the student responses before and after the Fall 2015 course to determine the number of students with "pro," "con," or "moderate" stances towards each issue, which allowed us to understand the degree to which each issue was polarizing, how many students changed their stance on an issue, and how many students had "moderate" stances that included consideration of potential alternative courses of action and positive or negative consequences of these actions.

Preliminary Observations and Reflections

The revised course using the decision-making heuristic was taught for the first time in the Fall of 2015. We found that a significant number of the students (twenty-five to thirty-eight percent across all four issues) changed their stances between pre- and post-assessment (Dauer and Forbes 2015). Other researchers acknowledge "changing one's mind" as a sign that effective reasoning and argumentation has occurred in the classroom (Grace 2009; Osborne, 2001). The overall pattern of student stances was significantly different between the pre- and post-assessment for each issue (Chi-square test; $P<0.05$ for organic, mountain lion and biofuel issues, $P=0.054$ for water issue). The number of students with a "moderate" stance decreased for the hunting mountain lion and organic food issues. For the irrigation and corn ethanol issues, there was a small increase in students with moderate

TABLE 1. Example Pre- and Post-Assessment Reasoning for Unit #4 (Water and Agriculture)

	Pre-Assessment	Post-Assessment
	"Con"	**"Moderate"**
What do you think should be done about this problem? Should we further restrict irrigation for agriculture in Nebraska?	"No, we need to keep irrigation for agriculture."	"The water should be in control by an elected group of farmers who all decide what should be done with the groundwater."
Why should we do it/not do it?	"Because we cannot allow these crops to die and not be watered. We need to make sure we produce enough food."	"This way the groundwater will be used responsibly and every [farm] will get its fair share. Also this group will be able to talk and coordinate how much they use per year to keep the water from running out."

TABLE 2. Example Pre- and Post-Assessment Reasoning for Unit #2 (Biofuels)

	Pre-Assessment	Post-Assessment
	"Pro"	**"Moderate"**
What do you think should be done about this problem? Should we burn corn ethanol for energy?	"We should burn corn ethanol for energy. If corn ethanol is going to be burned for energy and there are people that oppose that, then the public should be better informed on its benefits."	"We should burn corn ethanol for fuel but reduce the amount of corn that we use for fuel and use more of it for food and use more alternate biofuels such as cellulosic, or algae."
Why should we do it/not do it?	"Corn ethanol is [a] large part of Nebraska's economy. There is an ethanol plant in my hometown of A___ and it creates a lot of jobs. It is also a new source energy that be renewed."	"We should burn corn for ethanol to continue to have a sustainable fuel source so we don't completely run out of fossil fuel for energy. We should reduce the amount that we have to use though so we can use more of the world's corn crop to actually feed the growing population."

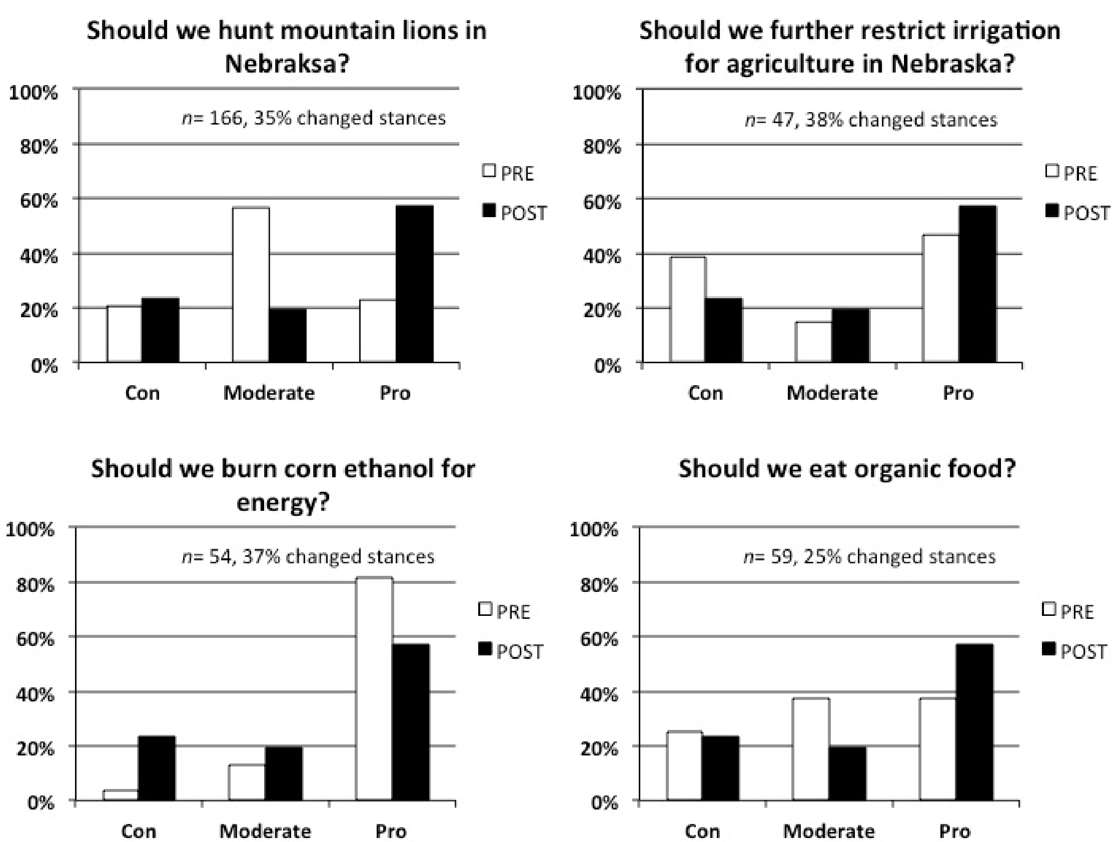
TABLE 3. Example Pre- and Post-Assessment Reasoning for Unit #3 (Mountain Lions)

	Pre-Assessment	Post-Assessment
	"Pro"	"Moderate"
What do you think should be done about this problem? Should we hunt mountain lions in Nebraska?	"Yes"	"I don't think we should be able to hunt mountain lions in Nebraska. I think the habitats are working out rather well. The only time they should ever be hunted is if they are showing a danger for people or their animals."
Why should we do it/not do it?	"I believe people should be able to hunt mountain lions in the Pine Ridge area because of how overpopulated it's becoming. I don't think there would be any animals in that area to thin it out naturally, so I think it's important for them to be hunted to do that."	"We should not do it because there aren't exactly many of them left. They aren't hurting anything unless they are actually showing a threat to humans or their animals. There's no reason to hunt them when they aren't doing anything to anyone else and aren't overpopulating."

stances. For these students, the moderate stance often reflected a more nuanced, informed and objective view on the issue. An example of a student who shifted from a "con" position on the pre-assessment to a more "moderate" position on the post-assessment is shown in Table 1. Other students exhibited more thorough and systemic reasoning to shift from a "pro" stance to a "moderate" stance, as shown for another student in Table 2. Some students exhibited increased learning about the parameters of the issue resulting in a shift from a "pro" stance to a "moderate" stance, as shown for another student in Table 3.

While we observed stronger, more sophisticated reasoning in some students' responses, more data analysis needs to be conducted to describe patterns in students' reasoning and to determine if the quality of students'

FIGURE 1. Preliminary data on Fall 2015 students' stances on each of the four issues discussed in the course pre- and post-instruction (Dauer and Forbes 2015).



arguments improved at the end of the course. Ongoing work is focused on determining if students were effective in using the seven decision-making steps in the context of the course, and if this practice influences students' informal decision-making about complex socioscientific issues.

Conclusions

The work presented here provided a foundation upon which to build a long-term research agenda around an innovative, high-enrollment course and engage in ongoing, empirically grounded instructional design. The course provides an opportunity for future work to describe how students leverage values versus scientific knowledge and information to solve complex socioscientific problems. Our long-term research goal in this setting is to reveal challenges for undergraduate students in integrating scientific information into real-world processes. This research will inform continued development of innovative teaching tools that guide postsecondary students in obtaining more robust science literacy skills.

Acknowledgements

Thank you to Olivia Straka for coding assistance.

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Jenny Dauer is an Assistant Professor of Science Literacy at the University of Nebraska-Lincoln. She is the lead instructor for SCIL 101. Her research interests include understanding how students mobilize knowledge and scientific evidence in their reasoning about socioscientific issues. Dr. Dauer has a Ph.D. from Oregon State University in Forest Science, an M.S. in Ecology, and a B.S. in Secondary Education from Penn State University.

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Appendix A:
Fall 2014 Pre- and Post- Assessment Questions

Directions: Please give as much information as you can about your opinion and why you think that way. It is important to understand that there is no right or wrong answer. We are just interested in your views.

1) Modern agriculture is very different from what it was 50-70 years ago. Food production has skyrocketed due to the emergence of chemical fertilizers, pesticides and herbicides, and seed development. Our current conventional agricultural production systems are often credited for saving billions from starvation. However, some people point to problems that arise due to conventional food production, for example: eutrophication of waterways due to chemical fertilizers, pesticides that unintentionally harm bees, frogs and bats, and potential effects of these chemicals or genetically modified food on human health. One solution proposed for these problems is organic food, which the US Department of Agriculture (USDA) classifies as not allowing synthetic pesticides, chemical fertilizers or genetically modified food. Additionally, some people advocate for organic food as being healthier to eat. What do you think should be done about this problem? Should we eat organic food?

Why should we do it/not do it?

2) Our culture is energy hungry! A relatively new way to solve our energy needs is to use biofuels. Biofuels are fuels made from living or recently living organisms. There are many sources of biofuels that create ethanol or diesel. A commonly used biofuel is corn ethanol. Currently 40% of the corn grown in the U.S. is used to create ethanol fuel. Corn ethanol is a boost to rural farmers, is a domestic source of energy, and some evidence suggests it may reduce carbon dioxide emissions into the atmosphere. Some people point to problems with corn ethanol including "food vs. fuel," sustainability, deforestation, and water resources. What do you think should be done about this problem? Should we burn corn ethanol for energy?

Why should we do it/not do it?

3) Should we hunt mountain lions in Nebraska? Mountain lions have recently recolonized the Pine Ridge area in the northwestern corner of Nebraska. Young male mountain lions have been documented throughout Nebraska including agricultural areas where suitable habitat may be limited. Nebraska Game and Parks recently opened a mountain lion hunting season in the Pine Ridge Unit in habitat that is suitable for mountain lions and where the population is growing. Last year there was a big debate in the Nebraska legislature around hunting mountain lions including issues of animal rights, human rights, safety, biodiversity and conservation. What do you think should be done about this problem? Should we hunt mountain lions in Nebraska?

Why should we do it/not do it?

4) The food we eat makes up more than 2/3 of our total water footprint because of all the water needed to produce that food. Nebraska irrigates approximately 10 million acres for agricultural production. That is more than any other state in the U.S., and more than every country except Mexico. Most areas in Nebraska currently do not restrict groundwater irrigation for agriculture. The groundwater is used from the Ogallala Aquifer, which, if depleted, will take over 6,000 years to replenish naturally through rainfall. What do you think should be done about this problem? Should we further restrict irrigation for agriculture in Nebraska?

Why should we do it/not do it?

PROJECT REPORT

The Clean Air and Healthy Homes Program: A Model for Authentic Science Learning

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Abstract

The Clean Air and Healthy Homes Program (CAHHP) is a science education outreach program that involves students in research of their own design related to indoor and outdoor air pollution and links with respiratory health. The program, which provides equipment, lesson plans, and support to middle and high school classrooms and professional development for teachers, is an excellent model of how to engage students in relevant and authentic science research and learning. This article describes the current program, how it promotes authentic science learning in secondary science education, and the positive impact it has had on student learning and attitudes.'

Introduction

Providing students the opportunity to truly *do* science has been shown time and time again to positively influence their science learning experience, including increasing students' interest in science (Ainley et al. 2002; Hasni and Potvin 2015; Palmer 2009; Potvin and Hasni 2014; Rivera Maulucci et al. 2014; Sadeh and Zion 2011; Spronken-Smith et al. 2012; Swarat et al. 2012). Other studies have reported that students engaged in inquiry-based learning focused on the process of science actually improved performance on achievement tests (Abdi 2014; Blanchard et al. 2010; Schneider et al. 2002). With the development and adoption of the Next Generation Science Standards (NGSS) (National Research Council 2013), teachers have been further encouraged to step away from the traditional teaching of discrete facts to a broader exploration of the world around us via inquiry-based learning. Through collaborative programs, there is now more opportunity than ever to engage students in the process of meaningful, authentic science learning.

The Clean Air and Healthy Homes Program (CAHHP) is a science education outreach program designed to offer middle and high school students the opportunity to explore a real-world issue through authentic scientific research in their homes and communities. Originally named *Air Toxics Under the Big Sky*, the program has evolved and grown significantly since its inception in 2003 (Adams et al. 2008; Marra et al. 2011; Ward et al. 2008). Its success and growth can be largely attributed to its adherence to SENCER ideals and to the early influence and support from the SENCER community, as originally reported in this journal in 2007 by Jones et al.

Through CAHHP, students learn about three air pollutants (particulate matter, radon, and carbon monoxide) that not only cause adverse health effects, but are also commonly found in indoor environments such as homes and schools. Exposure to airborne particulate matter can result in respiratory and cardiovascular diseases (Environmental Protections Agency 2016) while radon is the second leading cause of lung cancer behind cigarette smoke (National Cancer Institute n.d.). Carbon monoxide is responsible for an average of 15,000 poisonings and 500 deaths in the United States each year (Centers for Disease Control and Prevention 2014). By participating in CAHHP, students begin to understand the link between their health and their own exposures through authentic research and data collection.

CAHHP takes place over the course of an entire school year and engages secondary school students living in rural areas of Montana, Idaho, and Alaska in scientific research focused on indoor air quality issues. This indoor component is an important focus, as the average American spends over ninety percent of his/her time indoors (Klepeis et al. 2001). Since the program's inception in 2003, we have worked with thousands of students in more than 40 schools. In the current school year alone (2015/2016), we have more than 800 students doing research projects in the classrooms of 30 teachers. The program is being implemented in a variety of subject areas including chemistry, environmental science, physical science, IB Environmental Systems and Societies, and anatomy and physiology.

Overview of the Program

CAHHP has three primary goals: (1) to develop and provide inquiry-based, learner-centered instructional materials and opportunities; (2) to implement these materials in rural underserved areas; and (3) to provide professional development opportunities for teachers interested in environmental health sciences. The following overview summarizes the program's activities throughout the course of a year.

Professional Development

The first step for a teacher who wants to implement the program in his/her classroom is to attend a two-day summer workshop. During this time, teachers learn about the three pollutants (particulate matter, carbon monoxide, and radon), receive an overview of the available lesson plans, perform a number of the inquiry labs included in the program, discuss strategies for and the value of supporting student research, and receive training on the air sampling equipment that is provided to the classroom. Teachers also have the opportunity to interact with colleagues who teach in the same content areas to discuss classroom implementation strategies. Additionally, expert "veteran" teachers share insights on how to successfully support student research and integrate the program into the classroom.

Classroom Visits

The summer workshop is followed by a visit to the teachers' classrooms, either in person or remotely via Skype, by a member of the CAHHP team. A presentation is given introducing students to concepts regarding air quality and respiratory health, including an overview of the program.

Lesson Plans and Supplemental Materials

Teachers have a number of lesson plans available to them for student exploration of the air pollutants throughout the school year. All lessons were developed in partnership with expert science teachers, as well as with research scientists in the field of environmental health sciences. Each lesson is tied to state and national standards and promotes the three-dimensional model of learning supported by the NGSS, as well as at least one guided inquiry lab illuminating a key concept related to one of the pollutants, its formation, and/or related health effects. A summary of all available lesson plans available through CAHHP can be found in Table 1. Table 2 displays the various learning units in which the lesson plans fit within a variety of classrooms.

Designing and Executing a Research Project

Once familiar with the pollutants, students identify a testable question and design a research project. To identify their questions, they are encouraged to consider the indoor environments in which they spend the majority of their time (home, school, and work) and what their potential pollutant exposures are within these environments. They are also encouraged to consider their communities and the specific, possibly seasonal, air quality issues that may impact them. Students can use one of three pieces of equipment provided by the program (see Figure 1) to perform their research. After identifying their question and developing a hypothesis, students then collect and analyze their data. Examples of student research projects from recent years are found in Table 3.

Presenting Findings

At the conclusion of each school year, students and teachers are invited to visit the university campus to attend the annual CAHHP Environmental Health Science Symposium, during which they present and defend their work either via a PowerPoint presentation before a panel of judges and between 100-200 of their peers, or through a scientific poster. The top three projects in each category receive awards. For many students, this is the highlight of their CAHHP experience. Evaluation data show that students benefit from participation in the symposium in a variety of ways (Vanek et al. 2011). For example, students have reported increased self-confidence in their ability to respond to challenging questions and potential criticism, as well as understanding the importance of being well prepared and practiced.

For students who cannot attend the symposium, there are many other options for formal presentation of student findings, including regional and state science fairs, community health fairs, and individual school events such as presenting research at parent night. Participation in one of these events is key, as findings from a study focused on inquiry-based science curricular initiatives developed between 1998 and 2007 found that only about 10 percent of projects emphasized presenting and communicating findings (Asay and Orgill 2010).

Beyond Student Learning Opportunities

In addition to providing meaningful learning opportunities, CAHHP encourages multiple community partnerships. Groups such as the American Lung Association, state, city, and county health departments, and Area Health Education Centers (AHEC) have created mutually beneficial relationships with CAHHP that expose students to possible future careers in the field of science and provide them an opportunity to do work directly for the community. For example, in a collaborative effort between the Montana Department of Environmental Quality and a student from a high school Geographic Information Systems (GIS) course, an interactive map of radon levels from more than 500 homes in the state was generated. This highlights not just the aspect of collaboration, but also the potential for citizen science opportunities. Data collected by students can be compiled, mapped, and used to inform the public and warious agencies on trends in air pollution. Students also have the opportunity to directly improve the air quality in their schools and homes. One group of students found high levels of radon in their public school building and collaborated with a local radon mitigator to engineer and install a successful remediation system. Past monitoring of particulate matter levels in schools has resulted in heating/cooling system maintenance and even the replacement of the ventilation system in a wood shop at one school after consistently elevated particle levels were measured.

What Students Are Taking Away from the Program

Findings from an external evaluation showed that students who participate in CAHHP demonstrate a deeper understanding of the process of science, and express an increased interest in science as a content area (Ward et al. 2016). Students also consistently self-report an increased confidence in their ability to do science. For example, one student wrote that "the program taught me that I can work hard and have the ability to conduct a thorough experiment and be confident in my skills," while another reported, "The program taught me that I have the ability to accomplish anything I set my mind to and I became more interested in science."

Other comments from students on their own experience and academic growth include:

- "It was cool doing an experiment to actually benefit my school."
- "[The program] made me aware of how science can be relevant to my everyday life."
- "I learned how to properly test a question."

Conclusion

The value of authentic science learning opportunities for secondary science students cannot be emphasized enough. As our results indicate, involving students in the actual process of science, from the ground up, creates learning opportunities that improve science skills and motivation. Both of these are critical for keeping students engaged in the scientific field, as there is a delicate interplay between students having strong enough skills to feel confident pursuing science and their desire to do so. Over the last decade, *The Clean Air and Healthy Homes Program* has emerged as a successful platform for increasing students' interest in science—and interest in science as a career—while keeping with current trends in science education. The development and implementation of the Next Generation Science Standards (2013) are confirmation of the broader agreement that science learning needs to be multifaceted and must truly involve students in scientific ways of thinking and doing, not just in the memorization of scientific facts.

Additionally, when students do research within their own communities, they begin to realize that they have the

TABLE 1. Overview of available lesson plans

Particulate Matter Lesson 1: "What is Particulate Matter?"	Students explore different sources of $PM_{2.5}$ and PM_{10} using the Dylos DC1700, then observe particle formation in a micro-environment (i.e., petri dish). Students also begin to consider their own exposures to particulate matter.
Particulate Matter Lesson 2: "Health Risks of Particulate Matter Exposure"	Students assume the roles of different individuals with different health profiles in five age groups: infants, children, young adults, middle-aged adults, and the elderly. They then visit different environment stations (i.e., large city, rural agricultural area, etc.) that have differing sources of pollution and weather patterns. Based on these, they identify their potential health concerns.
Carbon Monoxide Lesson 1: "What are Complete and Incomplete Combustion?"	Students explore the reactants and products of combustion in the "Life of a Candle" lab. By subjecting a burning candle to differing conditions, they are able to deduce both visible products (soot) and invisible products (carbon monoxide) during incomplete combustion and determine the chemical equation of combustion.
Carbon Monoxide Lesson 2: "What are the Health Effects of Exposure to Carbon Monoxide?"	Students explore the physiological mechanisms underlying carbon monoxide toxicity by watching a video of a lab in which blood samples are exposed to different gases (O2, CO2, and CO) at different times. By observing blood color after exposure, students discover that CO bonds more tightly to hemoglobin and inhibits continued gas exchange.
Radon Lesson 1: "What is Radioactivity?"	This lesson introduces students to the origin of radioactive isotopes and how they interact with the environment through two labs: "Vapor Trails" in which students observe energy rays emitted by a radioactive source, and "Pennicium, Pennithium, and Pennium" in which students use pennies to simulate the decay process of different "isotopes" to determine the equation for half-life.
Radon Lesson 2: "What is Radon?"	Students learn about radon, its origin, and how it enters the environment. They examine radiation produced by different materials, how distance is related to radiation dose, and how various shields can alter the emission of radiation.
Radon Lesson 2: "What are the Potential Health Effects of Exposure to Radon Gas?"	To understand the relationship between radon exposure and respiratory health, students participate in a simulated epidemiology study to explore the correlation between radon and lung cancer.

TABLE 2. CAHHP Materials and Learning Units

	Particulate Matter	Radon	Carbon Monoxide
Physical Science and Chemistry	• Atoms and Compounds	• Nuclear Decay • Isotopes • Balancing Nuclear Equations	• Conservation of Mass
Biology	• Respiratory System • Genetics (epigenetics)	• Genetics (genetic mutation and cancer)	• Circulatory System • Respiratory System
Earth Science	• Meteorology		Chemistry

TABLE 3. Examples of student projects

Pollutant	Project Title
Particulate Matter	"Air quality in indoor swimming pools—An exploration of particulate levels in indoor pool facilities during low and peak use"
Particulate Matter	"Ski-entifically proven: Ski waxing in indoor environments"
Particulate Matter	"Roundabouts vs. traffic light intersections and their implication on air quality"
Carbon Monoxide	"CO output levels of different types of automobiles"
Radon	"Differences in indoor radon levels in Kootenai Valley homes with respect to soil type"

ability to collect meaningful data and to use that information to directly make a difference in their own lives and those of others in their community. They become stakeholders in their own well-being and have the potential to make tangible changes through their research. They also have the opportunity to meet and interface with professionals whose lifework is committed to improving quality of life for the average citizen through science. The more science becomes a concrete practice for students and not a set of abstract ideas, the more likely they will use and engage in science in their daily lives. In this way, programs like CAHHP provide valuable opportunities to make science learning more meaningful and effective. In the future, we will continue to engage schools in rural and underserved areas, supporting students in conducting authentic research focused on reducing exposures to air pollution while improving health within their homes and communities.

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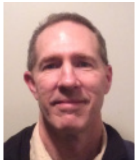

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PROJECT REPORT

Strengthening STEM Education through Community Partnerships

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Abstract

California State University San Marcos (CSUSM) and San Marcos Elementary Schools have established a partnership to offer a large-scale community service learning opportunity to enrich science curriculum for K-5 students. It provides an opportunity for science, technology, engineering, and math (STEM) majors to give back to the community, allowing them to experience teaching in an elementary classroom setting, in schools that lack the resources and science instructor specialization needed to instill consistent science curricula. CSUSM responded to this need for more STEM education by mobilizing its large STEM student body to design hands-on, interactive science lessons based on Next Generation Science Standards (NGSS). Since 2012, the program has reached out to over four thousand K-5 students, and assessment data have indicated an increase in STEM academic performance and interest.

Introduction

School districts across the state of California (CA) are failing to teach the scientific disciplines (Dorph et al. 2011; Rumberger 1985). More specifically, when elementary students receive science instruction, it is often of poor quality and in fleeting instances (Conderman and Sheldon Woods 2008). Only one in ten CA elementary students receives interactive and engaging science instruction on a regular basis (Schweingruber et al. 2007). The lack of instruction in science content is evident at all grade levels, but is perhaps most clearly apparent and detrimental in K-5 education (Rumberger 1985).

Due in part to the long history of the No Child Left Behind Act (NCLB) and the newly and widely adopted Common Core State Standards (CCSS), CA elementary students have received a disproportionate amount of their educational focus on mathematics and language arts (Cody 2013; Kelly 2000; Luehmann 2007; Windschitl 2002), resulting in minimal exposure to the sciences because they are not tested until the fifth grade (http://star.cde.ca.gov/star2012/AboutSTAR.aspx). As a result, students' levels of investigative inquiry are not evaluated or stimulated until the late stages of elementary education. Due to such late testing, the early teaching of science material is regarded as unimportant and not pertinent to students' "success" as elementary students, and this results in a lack of science instruction that fails to spark STEM interest levels among K-5 students (Avard 2009; Chubb and Chubb 2012; Goodrum et al. 2012; Goodrum et al. 2001; Herranen et al. 2015).

CA districts currently focus primarily on the core disciplines of English Language Arts (ELA) and Mathematics, where state funding is most heavily allocated, inferred from the focus of the Common Core State Standards. Districts adhering to the older NCLB increased instructional time by 43% for ELA and Math at the expense of STEM content, since conventional core disciplines such ELA and Math are regarded as crucial skills for the early academic development of elementary students. However, when considering early science education as a tool to promote critical thinking and analytic skills (Bailin 2002), it is distressing that the sciences are not also accepted as a core discipline. As a response to the lack of science in the classroom, children become isolated from the scientific process and even intimidated by the subjects, creating a pattern that denies them insight into investigative thinking and problem solving. These formative years are crucial not only for providing students opportunities to get excited about STEM content, but also to prepare them for later years of intense science exposure in their education. Furthermore, early exposure to science may set more students on a STEM- specific professional path for later life (Lyon et al. 2012; Tai et al. 2006).

Lack of professional development and teacher interest in science instruction is also a problem in elementary school education (Abell and Roth 1992; Epstein and Miller 2011; Tilgner 1990). With consistent exposure to ineffective and ill-prepared classroom instructors, students suffer in science and mathematics when compared to students who work with highly trained teachers (Abell and Roth 1992; California Council on Science and Techology 2010; Tilgner 1990). Without persistent incorporation of the sciences into school curricula, teachers are not prepared to effectively teach the subjects, and there is a lack of specialized science instructors to fill this gap (Abell and Roth 1992; Avard 2009; California Council on Science and Techology 2010; Herranen et al. 2015; Tilgner 1990).

California has shown a strong commitment to standards-based learning through its adoption of the Common Core State Standards (CCSS), which were largely developed by National Governors Association Center for Best Practices and the Council of Chief State School Officers, incorporating input from K-12 teachers and administrators, state leaders, and education experts (http://www.corestandards.org/about-the-standards/frequently-asked-questions/ and http://www.corestandards.org/assets/CCSSI_K-12_dev-team.pdf)(CCSESA 2013). The main goal of the CCSS is to equip students with the necessary skills in ELA and Mathematics to prepare them for success in a post-high school environment, whether it is post-secondary education or the workforce. However, within the general literacy framework of the CCSS, there are three main concerns from the perspective of early STEM education: the CCSS do not cover investigative and inquiry based science education until the fifth grade; the CCSS are meant to be interpreted at the state and local levels by school administrators; among the 135 members who wrote and reviewed the CCSS, there were no early childhood professionals or K-3 teachers (Miller and Carlsson-Paige 2013). Not providing detailed STEM education and assessment until the fifth grade is detrimental in itself, but there are other aspects of the CCSS that further hinder early STEM education. The CCSS do not call for the training of STEM educators; rather the CCSS prompt teachers and administrators to adapt the CCSS according to their own vision. Granting more flexibility to local levels for decision-making and interpretation of the standards is likely to marginalize STEM education due to the initial lack of resources and specialized instructors allocated for STEM education (California Council on Science and Techology 2010). The sciences are often overlooked or oversimplified as a result of being deemed too difficult or underfunded to implement. This leads administrations to focus more on traditional core disciplines, or to cut corners in science education and teach shallow concepts. With so few professional science educators as part of the development process (Franz and Enochs 1982; Hurd 1970), insufficient facilities and equipment (Tosun 2000), and poor teacher attitudes (Koballa and Crawley 1985) there is little optimism that a STEM curriculum would receive the attention and championing from administrations that would be required for STEM incorporation into the K-5 curricula.

The Next Generation Science Standards (NGSS)

The National Science Education Standards from the National Research Council (NRC) and "Benchmarks for Science Literacy" from the American Association for the Advancement of Science (AAAS) have historically acted as guidelines for states in the development of state specific science standards, and in this case the CCSS (http://www.nextgenscience.org/frequently-asked-questions#1.1). However, these documents have become obsolete in the last fifteen years as advances in science and effective science pedagogy have been made. Thus, the NRC created a framework with new definitions about what it means to be proficient in science. Experts in the fields of science, engineering, cognitive science, curriculum, assessment, and education policy were involved in the developmental process of this framework that would ultimately be the foundation for the NGSS (http://www.nextgenscience.org/frequently-asked-questions#3.1). The mantra assumed by this framework was that employability in the 21st century would largely depend on skills based in the sciences and mathematics (Langdon et al. 2011; Stine and Matthews 2009). Along with reading, writing, and communication skills, the NGSS recognizes aptitude in science and mathematics as equally important for integration into the workforce. Rather than leaving its standards up for interpretation, the NGSS clearly defines what science concepts ought to be taught, as well as how to establish connections between cross-disciplinary concepts. This is one of the ways in which the CCSS have failed in the past: not only do they fall short in establishing core science instruction, but they make no effort to create relationships between different subdisciplines within the sciences, such as medicine and plant biology. When students can identify and bridge the gaps between two or more science subdisciplines they are able to exercise an improved intrinsic understanding of the concepts involved by seeing how each discipline acts independently in addition to how the disciplines act in tandem.

The move towards the NGSS is very district/school specific, but at a state level CA first started to implement the NGSS system in 2013 in the context of a continuous learning process. The plan consists of installing three main phases (the awareness phase—introduction to the CA NGSS [2013-2015], transition phase—building foundational resources [2015-2018], and the implementation phase—fully aligned curriculum [2016 and beyond]) (California Department of Education 2014). The NGSS were in part developed to reflect the type of job distribution expected for the future. The National Science Foundation "estimates that eighty percent of the jobs created in the next decade will require some form of math and science skills." Even if students do not pursue a STEM-based career, the benefits of including more STEM content at all education levels include problem solving, independent thinking, and literacy in the workings of the natural world (Brophy et al. 2008; Bybee 2010; Eshach 2003; Katehi et al. 2009; Portsmore and Rogers 2004; Sanders 2009).

Tackling the Lack of Early Science Experiences through Service Learning

In 2011, a small team of CSUSM STEM faculty recognized this dilemma and proposed to conduct a two-week after-school science enrichment program in partnership with Twin Oaks Elementary School (TOES), a local K-5 school in the San Marcos Unified School District (SMUSD). The principal and CSUSM STEM faculty were overwhelmed with the response of more than a hundred parents who gave permission for their children to participate in the after-school science program. The participating children were thoroughly engaged in the pilot program and the parent feedback was supportive, indicating a strong desire to continue with the program in the future.

After realizing the success, there was an immediate desire among the participating CSUSM faculty to install a more substantial and embedded STEM project-based learning outreach program (Goebel et al. 2009; Han et al. 2015; Perkins et al. 2015). STEM project-based learning is an instructional strategy that is student driven, interdisciplinary, collaborative, engaging, and hands-on/technology based (El Sayary et al. 2015; Han et al. 2015; Larmer et al. 2015; Savery 2015). Capitalizing on the student body within the College of Science and Mathematics, faculty recruited STEM undergraduate majors interested in helping on the project. Teams of CSUSM students were tasked to develop hands-on, experiential science lessons that were based on the Next Generation Science Standards to supplement elementary curricula using the "5E's Learning Cycle Model"—Engage, Explore Explain, Elaborate, Evaluate— from the Biological Science Curriculum Study (BSCS) (Bybee et al. 2006). The goal was to create one-hour-long lesson plans that encouraged inquiry-based and hands-on learning to excite these young students with innovative learning experiences (Christensen et al. 2015; Greenspan 2016; Hampden-Thompson and Bennett 2013; Shelton 2016).

In Fall 2012, these first lessons were designed and administered to every K-5 classroom at TOES, reaching over 850 elementary school children and incorporating sixty college students who acted as instructors.

Program Extension

The program eventually evolved into a large-scale community service project, involving the recruitment of 220 STEM majors from across fifteen courses each semester. As a result of the increase in the number of participants, the program expanded in the spring of 2013 to include another local Title 1 elementary school, San Marcos Elementary (SME). At SME, the teaching model adopted was slightly different. Specifically, all fifth grade classes received one hour-long lesson per week for six weeks, with a different NGSS standard addressed each week. This different model was created in order to evaluate student retention of the STEM content taught, using pre- and post-assessments. The TOES program, although without assessments, continued to deliver a lesson to elementary school students at all grade levels each semester.

Methods

Recruitment of CSUSM Science Majors

CSUSM professors offered service learning as an extra credit option in many of the core science curriculum classes that students must take in order to fulfill their science degrees (Table 1). Recruitment from these classes resulted in a large enough student participant pool (180-220 undergraduate students) to cover 40-54 lesson plans a semester.

Lesson Plan Development

In order for CSUSM undergrads to receive the extra credit for their participation, they had to satisfy a number of program requirements in addition to preparing a lesson plan based on assigned elementary standards intertwined with curriculum content covered in their own college-level classes. Students interested in the program were invited to an online module where they selected a K-5 grade to sign up for on a first-come, first-served basis. Depending on the grade level they signed up for, undergrads were assigned a presentation date and group partners who also signed up for the same presentation date. Through the module students gained access to important information and instructions for the program, including the ability to use a discussion board, select times for rehearsal sessions, and review general guidance for the program. Groups consisted of two to three STEM-based undergraduates assigned with an Integrated Credentials Program (ICP 381) student or a CSUSM Noyce Teacher Scholar. The Noyce Scholars is a program that responds to the critical need for K-12 teachers in STEM fields by encouraging talented STEM students and professionals to pursue STEM teaching careers. STEM undergraduates designed engaging experiments and brought forth content knowledge, while ICP and Noyce Scholars contributed a pedagogical perspective by conducting classroom management training and translating science concepts into age-appropriate lesson plan material.

To obtain credit for completing the project, students had to satisfy five main requirements that defined the outreach program rubric. The first was to attend an orientation. The orientation explained the overall purpose and goals of the program and provided detailed explanations of the lesson plan rubric, due dates, and expectations. Here the students had the opportunity to meet the directors of the program and ask specific questions. All the information from the orientation was accessible on the module, with additional discussion forums where students could ask follow-up questions.

The second component of the rubric was designing a lesson plan. Groups were given two weeks to collaborate on a lesson plan for their selected grade via electronic communication and in-person meetings. They collectively selected their lesson plan topic (while still adhering to the subject matter of their university level class and their respective elementary grade level standards) unless the elementary class requested a specific topic in advance. All the lesson plans were developed from the "5 E's Learning Cycle Model" (Bybee et al. 2006). This model provided clear delineation of a lesson plan into five main sections: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each lesson plan began with an "Engagement" activity designed to quickly stimulate student interest while pre-assessing their prior understanding of the subject. Engagement activities capture students' interest and help them to make connections with what they may already know about the subject. Most engagement activities consisted of short instructor demos, videos, or a classroom activity to swiftly capture student interest. Next was the "Exploration" phase, where students encountered hands-on experiences in which they explored the concept further. They received little explanation and were encouraged to collaborate with peers to define the problem or phenomenon in their own words. The purpose of this stage of the model is for students to acquire a common set of experiences from which they can help one another make sense of the concepts and observations. Students must spend significant time during this stage of the model talking about their experiences, both to articulate their own understanding and to understand other peers' viewpoints. The "Explanation" section provides the scientific explanations and terms for the topic under investigation. CSUSM students presented the concepts via lecture, demonstration, PowerPoint, or other multimedia. Undergrads were reminded to avoid strict lecturing in this phase and instead encouraged to keep the classroom discussion as interactive as possible. Students then used the terms to describe what they had experienced thus far in the presentation and began to mentally examine how this explanation fit with what they already knew. In the "Elaboration" phase students were given an opportunity to apply the concepts they had learned by conducting an experiment that the undergrads set up. Peer to peer interaction was essential during the "Elaboration" stage. By discussing their ideas with others, students could construct a deeper understanding of the concepts. Crucial to the experiment was a hands-on component where students had a chance to use instrumentation, make observations, record data, and reflect upon

TABLE 1. Classes that participated in the service learning STEM project. Students in the Integrated Credential Program (ICP) are liberal studies students in a combined undergraduate and elementary teacher credential program. There was at least one of these students per group to provide experience in teaching strategies, while the STEM major students provided content.

Class	Participating Semester
Animal Physiology (Bio 353)	Fall 2013, Spring 2014, & Fall 2014
Biochemistry (Chem 341)	Spring 2013 & Fall 2013
Biotechnology (Bio 355)	Fall 2014
Evolution (Bio 212)	Spring 2013, Fall 2013, & Fall 2014
Genetics (Bio 352)	Fall 2013, Spring 2013, & Fall 2014
General Biology (Bio 210)	Spring 2013 & Fall 2013
Integrated Credentials (ID 381)	Spring 2014
Microbiology (Bio 367)	Spring 2013, Fall 2013, Spring 2014, & Fall 2014
Molecular Cell Seminar (Bio 560)	Spring 2013
Molecular Cellular Biology (Bio 351)	Spring 2014
Organic Chemistry II (Chem 202)	Fall 2013 & Spring 2013
Physics (Phys 380)	Fall 2013 & Spring 2013
Physics (Phys 202)	Fall 2014
Protein Structure & Function (Chem 450)	Spring 2013
Virology (Bio 504)	Spring 2014

their findings (Greenspan 2016). Finally, an "Evaluation" section concluded the lesson plan. It was designed to allow the students to continue to elaborate on their understanding through interactive classroom discussion and to evaluate what they knew now and what they had yet to figure out. Evaluation of student understanding should take place throughout all phases of the instructional model; in the "Evaluation" stage, however, the teacher determined the extent to which students had developed a meaningful understanding of the concepts. The last ten minutes of the lesson were dedicated to answering student questions about college. The elementary students had the opportunity to ask the CSUSM students about their experiences, which built a role model relationship.

A template lesson plan was provided on the module for the students to use so that finished lesson plans were all uniform in the 5E model. The requirements for the lesson plans were K-5 standards-based, focused on hands-on experiences and interactive engagement and contained both a data collection component and a take-home component. The goal was to have each lesson plan written in such detail that in the future any elementary school teacher, specifically those with non-STEM backgrounds and little experience teaching STEM content, could comprehend and completely implement the lesson plan from start to finish. Upon completion of a first draft, lesson plans were uploaded to the module, where they were edited and annotated by at least one individual—the graduate student coordinators, CSUSM faculty, or an elementary teacher for feedback and advice. The undergraduates then adapted their lesson plans, based on those recommendations, and resubmitted a final draft, which was again looked at by another member of the committee. Once the lesson plan gained approval, the group attended one or two mock sessions, which could be scheduled through the module, depending on the coordinators opinion of how prepared the group was to present in the classroom. If the lesson plan was not satisfactory, it was sent back for a rewrite along with assistance from one of the program directors. In the end, each lesson plan was approved by the program directors, a CSUSM professor and an elementary teacher. We used the following criteria to approve the lesson plan: were all the components of the 5E lesson plan completed, were the main objective and standards clearly articulated, was it clear what the children as well as the presenters (CSUSM students) would be doing at each stage of the lesson, and what was the take-home message?

The third component of the rubric was to attend a mock session. Here undergrads ran from start to finish through their lesson plan in front of program directors to gain approval on lesson plan items such as their featured experiment, physical materials, worksheets, PowerPoints, and multimedia. Groups demonstrated their experiment or provided a video of the experiment to prove that it was legitimate and well thought out. If the committee decided the group was not ready to present, then they were asked to attend another mock session. Other details such as classroom organization, teaching tips, attire, and etiquette were addressed as well. Any necessary science equipment required for their lesson plan was documented and requested by program directors to be borrowed from various CSUSM departments. Program directors then made the equipment available on the day the undergrads presented at the elementary schools.

The fourth component of the rubric was to present the lesson to their designated classroom. Each group arrived 30 minutes prior to the presentation start time, so that they could collect their equipment and set up the classroom. After completion of their lesson they were responsible for cleaning the classroom.

The fifth component, and to get full credit for the program, undergrads had to fill out a final reflection survey and a peer review evaluation located on the module. The surveys addressed questions about their experience with the elementary students and program administration and their interests in teaching, as well as their desire for future participation in the program.

Pre- and Post-Assessments

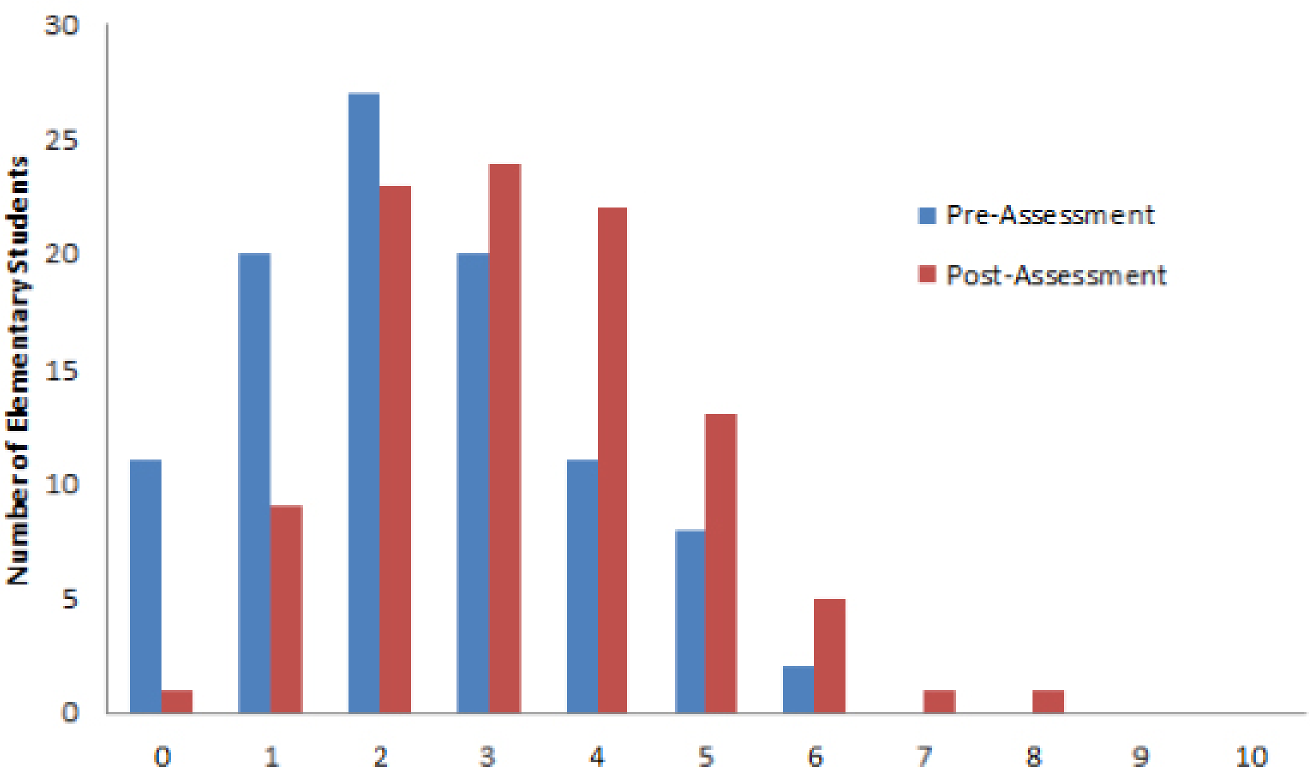
The San Marcos Elementary School (SME) model was identical to the TOES model except that only fourth and fifth grade classes were targeted due to the number of participating undergrads available. Fourth and fifth graders were the primary target age range, since fifth grade is the year students are STAR (California Standardized Testing and Reporting) tested in science for the first time. The goal for this SME model would be that the same class of students would receive science instruction for three to six weeks in a row and then be assessed for their retention of the material with pre- and post-assessments to determine if there were any measurable effects. The evaluation questions were multiple choice questions taken from released California Content Standards Tests as part of the STAR Program. There were twenty questions selected at random for the assessment. The Online Assessment Reporting System (OARS) (http://www.redschoolhouse.com) were used to data-mine and correlate the pre- and post-tests. With OARS, we were able not only to identify specific standards the students improved on; we were also able to predict their possible percentile score on the California exams. All pre- and post-assessments were also analyzed using a paired end t-test with a 0.05 significance as previously established in Fraenkel et al. (1993).

In the first SME semester (Spring 2013 cohort) the evaluations were given to thirty-two students (out of 137 students) who were selected to be a representative cohort of the entire fifth grade population. This cohort consisted of one entire class that received the science instruction who placed together based on previous performance in language and math state assessments in the previous year (STAR testing; http://star.cde.ca.gov/star2012/help_scoreexplanations.aspx). There are four categories of STAR results: Advanced, Proficient, Basic, Far below/Below basic. Eight students in this class fell into each category, yielding the thirty-two students. The next semester (Fall 2013 cohort) every fifth grade class at the school was evaluated with a new set of questions. The pre-test was administered by SME teachers one week before the lessons began during school hours. The post-test for the Spring 2013 semester was administered a week after finishing the six weeks of lesson plans. In the Fall 2013 session, the post-assessment was administered the following semester, a total of four months after completing the lesson plans to see if the students understood the material or just had short-term retention following the lessons.

Research

Over the past three years, the CSUSM STEM Program has delivered 125 lesson plans and provided over 4,000

FIGURE 1. Results from the Spring 2013 pre- and post-assessment (n=30). Mean score for the pre- assessment was 6.5 (sd=3.145), and the mean increased to 11.2 (sd=2.389) in the post- assessments.



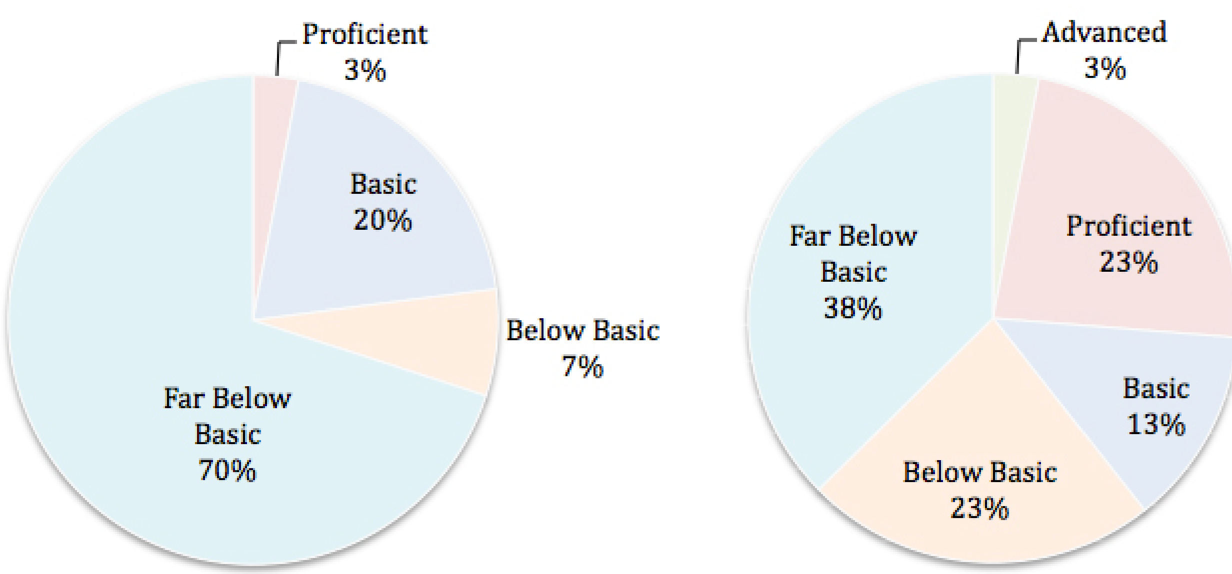
instances in which students at two neighboring elementary schools engaged in hands-on and experiential learning encounters with science. Lesson plan topics range from chemistry, physics, and engineering to physiology, botany, and many other subdivisions of biology. Hands-on experiments range from dry ice demos, growing yeast balloons, launching bottle rockets, microscopy of viruses, periodic element games, and centripetal force demonstrations to creating plant biomes and countless others. CSUSM undergrads have been able to come up with unique and creative ways to address the California State Standards and NGSS while creating a step-by-step lesson plan so that any non-STEM instructor would be able to confidently and successfully create an engaging hour of science.

In the Spring 2013 cohort, 32 students out of 137 from SME were selected to be a representative cohort of the entire fifth grade student population, as they reflected an equal representation of each of the performance groups in language arts and mathematics. These students completed a 20-question pre-assessment test and then retook the same 20-question test as a post-assessment after their six consecutive weeks of lessons given by CSUSM college students. During this time there was no additional science given to the students in their regular elementary classroom environment. The post-assessments showed an increase in academic STEM performance. On average the students increased their test scores by 4.7 points ($t = -8.5925$, $df = 29$, p-value = 1.83e-09; Figure 1) after the completion of CSUSM lesson plans.

For the Spring 2013 model, the Online Assessment Reporting System (OARS) was used. This information was rearranged into Figure 2 showing the results from the pre-assessment and the corresponding post-assessment for that semester. In the pre-assessment, 70% of the students tested in the Far Below Basic category and only 3% tested into the Proficient level (national goal). There were no students who tested into the Advanced level. After just six weeks of science instruction, there was a 33% decrease in the Far Below Basic and a twenty-three percent increase into the Proficient level. There was even a 3% increase into the top Advanced level.

Instead of teaching all the fifth grade classrooms for six weeks, the program was adapted to cover both the fourth grade classrooms and the fifth grade classrooms for three weeks in a row. The idea was that the fourth graders would eventually have two rounds of the program before being assessed in the fifth grade and four rounds before entering middle school. To see the effect of having only three weeks of consecutive lesson plan education,

FIGURE 2. A) Pre-assessment results for SME model (fifth grade) in Spring 2013. B) Post-assessment results for SME model (fifth grade) in Spring 2013.

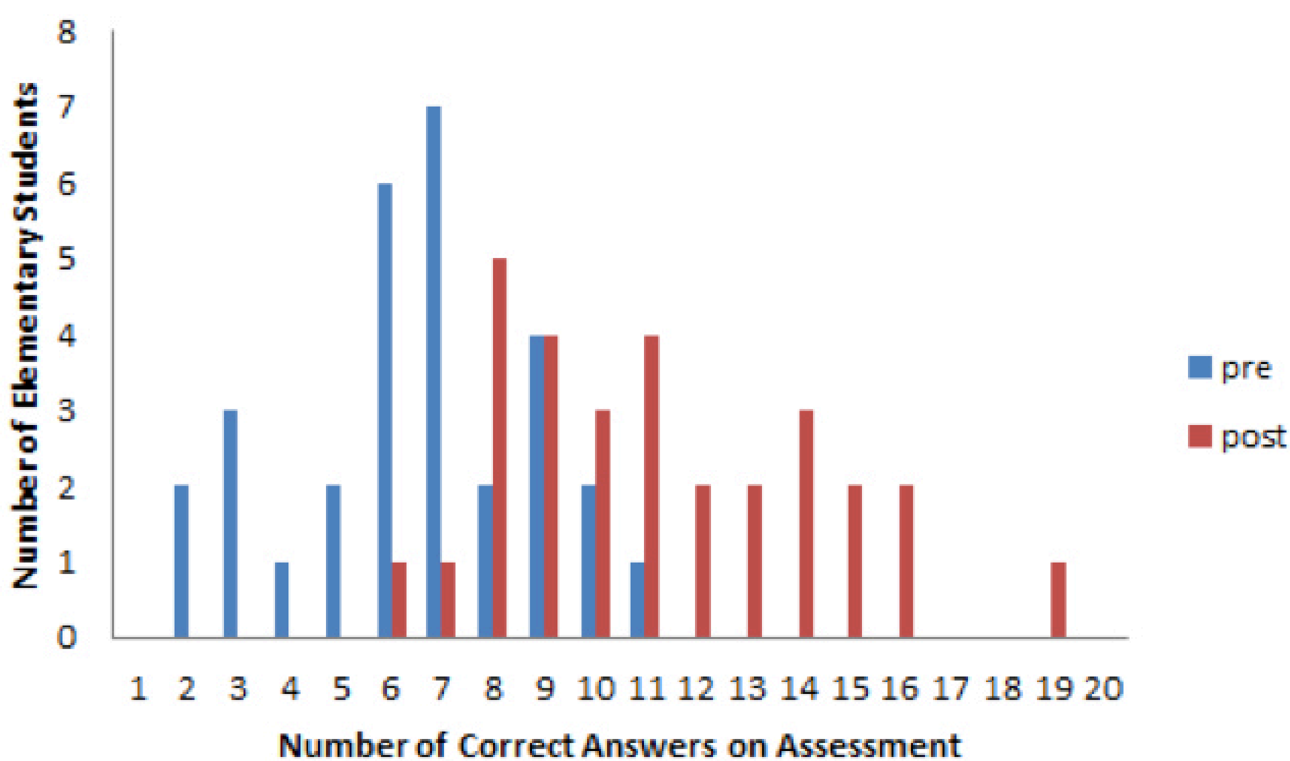


every fifth grader at SME was evaluated before the start of the lesson plans implementation. Unlike the Spring 2013 cohort, these students took the post-assessment test the following semester to truly demonstrate information retention of the lesson plans education. The results of post-assessments again showed an increase in academic STEM performance. On average the students increased their test scores by 0.96 points ($t = -5.514$, $df = 98$, p-value = 2.849e-07; Figure 3) after the completion of three weeks of CSUSM lesson plans. Hence, from these two pilot cohorts, six weeks of instruction resulted in a greater increase in performance after the exposure to science lessons, although there was also an increase after only three weeks of instruction.

After only a single but very engaging lesson on elements and the breakdown of the periodic table, there was a huge increase in answering two of the post-assessment questions. An example of these questions was "A student is grouping elements by chemical properties. According to the periodic table, the element with similar chemical properties to carbon (C) and tin (Sn) is a) gold (Au), b) calcium (Ca), c) nitrogen (N), and d) silicon (Si) [Correct answer]. More than half the students who initially answered incorrectly on the pre-test were able to answer it correctly on the post-assessment. Towards the start of that semester the students were exposed to a chemistry lesson on the periodic table trends through the use of an engaging game. This game emphasized periodic trends such that elements near each other on the periodic table share chemical properties. By making this activity into a game, played against their peers, there was an increase in student involvement, leading to an increase in information retention. Such an activity, whether it be an in-class game or an interactive hands-on activity, can transform the process of learning science content into a fun and memorable experience; an experience that leads to an increase in students' scores from pre- to post-assessment.

The STEM outreach also has a positive impact on CSUSM STEM majors. The overall feedback at the end of the semester was positive from both the elementary students/teachers and the CSUSM undergrad students/

FIGURE 3. This graph displays the results from the Fall 2013 pre- and post-assessment (n=99). Mean score for the pre-assessment was 2.323 (sd= 1.499), and the mean increased to 3.283 (sd=1.504) in the post-assessments.



faculty. We collected feedback data from the CSUSM participants through a survey presented online. There was an overwhelming positive response to the program in its entirety. Not only were there positive gains in the elementary school test scores but the survey also showed that 87% of CSUSM students proved to have had a rewarding experience. In fact, as a result of their experience, 43% of the CSUSM students actually started considering teaching as a career path. Ninety-seven percent of the students recommended that the program continue, and 80% of the CSUSM students reported they had learned something new that would benefit them in their future career path. Each year the program grows, and as directors we have adapted its design to what works and have accommodated all the new additions. The program was not based on a previous model but was created on the basis of a conversation between an elementary school teacher and a CSUSM professor, indicating the authentic and truly collaborative nature of the work.

Discussion

This large-scale program has successfully developed a model to deliver hands-on science lessons to elementary school children by college STEM majors. The program was implemented as result of the strong partnership between the local elementary principals and CSUSM faculty. This program served two Title I schools in the SMUSD. These schools do not have the resources, including time and expertise, to deliver high-quality, impactful hands-on science instruction. Only six extra hours of engaging hands-on lesson plans implemented by STEM undergrad role models was enough to improve the elementary students' retention and interest in the subjects.

It's important to note that most of the assessments and lessons were given prior to the initial release of NGSS and were based on the previous California state standards. As soon as the NGSS were released in CA, however, we immediately began to design our lesson plans to include the NGSS aspects. Our goal was to develop hands-on lessons that would provide meaningful engagement for the children. Coincidentally, this is also the emphasis of NGSS. The NGSS science and engineering practices involved asking questions, developing and using models, planning and carrying out investigation, analyzing and interpreting data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The DCIs (disciplinary core ideas) were the primary target in the design of the lesson plans since they are as close as the NGSS has come to setting standards, while XCCs (cross-cutting concepts) were used minimally during the lessons. This was primarily because the idea of XCCs had not been fully developed or released at the time of the initial lessons. However, XCCs could well be incorporated into future lessons. Finally, SEPs (Science and Engineering Practices) would involve explaining a concept or phenomenon by using or creating models. This is practically the core to our lessons; all are engaging and hands-on.

Elementary students experienced an overall increase in retention of knowledge and STEM academic performance in all our cohorts. The Spring 2013 cohort had a greater improvement, most likely due to a longer exposure to more lesson plans. However, even in the Fall 2013 cohort, when this time frame was cut in half to three weeks, we were still able to see an increase from the pre- to the post-assessments. This illustrates the dramatic effect on students when they are given hands-on, engaging experiments. These experiments stimulated students' interest, which led to an increased retention of knowledge of the material, ultimately facilitating a better understanding of the subject matter and content. The Fall 2013 cohort was tested four months later, and the students were still able to retain much of the information from the lessons given by the CSUSM students. There was also a notable increase in the elementary students' interest levels in STEM fields from the start to the finish of the program. By the end of the program, the students were announcing that science had become their "favorite subject." This program helped bridge these students from viewing science as an intimidating and hard subject to a familiar and fun enterprise.

From the exit survey for the college students it was reported that the program also increased undergraduate interest in teaching, which was an added benefit of the program (Borgerding 2015; Certificates 2008; Moin et al. 2005; Tomanek and Cummings 2000; Worsham et al. 2014). The survey also showed that this extra credit opportunity benefited the students by improving their understanding of the college-level course from which they were initially recruited. The college students elaborated that the ability to teach a complex topic that they were studying to students at an elementary level was a true challenge and tested their own understanding of the topic. As a result, the faculty members at CSUSM have had a positive response to continuing to offer this opportunity to their students.

The program has also created a partnership in the San Marcos community, between elementary students and college students. These young elementary school students are repeatedly surrounded with intelligent and successful college-level role models instilling in them the notion of achieving a college degree. The CSUSM undergrads served as role models for the children in multiple ways: clarifying misconceptions about college life, encouraging the importance of attending college, exemplifying proper behavior as a college student, and inspiring them with the notion that college was a feasible achievement (Bruce et al. 1997; Marks et al. 2004; McMinn 2015; Schmidt et al. 2004; Sjaastad 2012; Tierney and Branch 1992). It was verified that the children viewed the college students as role models through verbal cues indicating the children's new desire to attend college and become a scientist just like their college student instructor. An additional benefit of the program is that the CSUSM student body that participated was reflective of the children in the community. Specifically, CSUSM is a Hispanic Serving Institution with about 34% of students self-reporting as latino/a (https://www.csusm.edu/communications/cougarstats/). These students continue to serve as great models in our community, especially in our project, where the elementary schools served have higher numbers of latino/a students, 64% at Twin Oaks Elementary (Jacobsen 2015–2016) and 95.3 percent at San Marcos Elementary (Wallace 2012–2013). As a result, not only were the CSUSM students experts on the topic but they were of the same ethnicity as the students and were seen as a success story about going to college: the elementary students could see their STEM teachers as role models for themselves.

This partnership could be easily replicated and repeated in other universities, with neighboring local elementary schools. The model has been shown to be effective in raising awareness of and interest in STEM education. The CSUSM program has been contacted by other elementary and middle schools with hopes of expansion to their schools, both inside and outside of the SMUSD. We anticipate the expansion of the project to other elementary schools while still maintaining the SME and TOES models. It would also be beneficial to track the undergraduates who reported an increased interest in teaching after participating in the program to see if they eventually did start to take education classes. We would also like to compile all the lesson plans we have collected and make them readily available for elementary school teachers. We expect to continue assessing our results each semester, to measure improvements in standards-based testing, to identify program areas that need enhancement, and to compile data for future funding and expansion.

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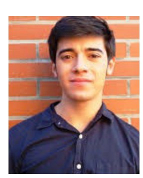

Jon Rocha completed his Bachelor's degree at the University of Southern California. He worked as an assistant on the STEM service-learning project in 2015 and in

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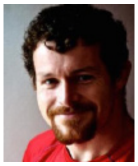

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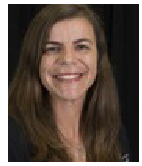

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PROJECT REPORT

Smart Moves: Making Sense of the Math in Environmental Data

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Abstract

Environmental organizers and their constituents, local community group members concerned about environmental health, operate in a context with rich and varied opportunities for learning about and applying mathematics to communicating environmental data. Prior to Statistics for Action, project partners—organizers at environmental non-profits—spent little time with group members analyzing data. Organizations did not have a method or protocol for considering the most effective way to frame findings for neighbors and decision makers. During the Statistics for Action Project, STEM educators and environmental organizers collaborated to use the context of environmental organizing as a platform for science and math learning. This article describes Smart Moves and Memorable Messages, two approaches that advanced goals for both math learning and organizing.

Rationale and Significance

Community members who live close to polluting facilities or toxic sites are often among the first to recognize the threats to human health. The historic pattern of placing polluting industries in or near low-income neighborhoods means that residents in these communities carry an unequal burden of negative health effects from environmental contamination (Faber and Krieg 2002). Bolstering the effectiveness of community groups organizing to clean up, curtail, or close down polluting operations has the potential to make a positive difference in human and environmental health. Local community groups that are well organized often prevail, gaining environmental protections and limiting negative health effects (Bullard 1993; Scammell and Howard 2013; see also annual reports for organizations such as Center for Health and Environmental Justice[1] and Toxics Action Center[2]).

1 http:// http://chej.org/wp-content/uploads/CHEJ-Annual-Report-2015.pdf (accessed June 22, 2016)

2 http://www.toxicsaction.org/about/mission-and-history (accessed June 22, 2016)

The *Statistics for Action* (SfA) project brought adult educators together with environmental organizers to create and test a set of activities and guides. The goal was to promote math and science learning for community group members involved in environmental campaigns in a way that would strengthen data-driven advocacy efforts. Organizing provokes concern and motivates concerned residents to action. Attention to science and math learning may happen as part of a larger organizing effort. Generally it is a means to an end. In spite of differing priorities, SfA project partners saw potential benefits to promoting math and science learning in the context of community organizing.

After a few false starts, SfA's team of educators and organizers agreed on messaging with data as an area of focus. Typically when organizers and community members query experts and regulators, they are treated to a fire hose of information. Daunting amounts of data call for strategies for both making sense of data and communicating key points once they are identified. Thus, the project's educators drafted a set of "Smart Moves" for math learning. Organizers embraced the norms for guiding mathematically rich conversations. The Smart Moves and SfA communication activities described below can be a useful starting point for other projects blending environmental advocacy and education.

Background and Questions

While observing community group meetings, science and math educators found that most groups struggled to make sense of technical documents such as environmental quality reports and standards for contaminants. Among these groups, three strategies for managing environmental data in technical documents were evident:

- Avoid the data and analysis altogether; focus on other tasks
- Find an expert to assist
- Delegate data management to a group member with a science, math, or engineering background.

Given that international assessments paint a dismal picture of U.S. adults' basic numeracy skills (Goodman et al. 2013), such strategies make sense. By opting out, delegating, or contracting out a careful look at the technical documents, however, groups often lose out on the opportunity for all of their members to use data in creative ways to advance their cause. What if a fourth strategy were viable? The project's formative research examined to what extent environmental organizers who are trusted by local community group members could be conduits for science and math learning. Project leaders, partners, and evaluators were convinced that if provided with a robust set of resources, organizers could effectively facilitate math learning. Project partners envisioned that with guidance from an organizer, all members of a community group would engage with local environmental test results, and in the process gain increased confidence in communicating the processes and findings to neighbors and decision makers. Educators on the project team also hypothesized that group norms or ground rules would be critical to establishing trust and engagement for doing math in community group settings.

Context and Players

Over 50 organizers used draft versions of SfA's activities and guides to promote understanding of environmental testing (final versions are available for free at sfa.terc.edu). Organizers worked in cities, towns, suburbs, and rural communities in North Carolina, California's Central Valley, New England states, and Chicago, Illinois. Prior to applying for funding, math educators interviewed staff at nine environmental organizations leading a variety of campaigns seeking improved environmental quality and advocating for human health. Four of the interviewees recognized the potential benefits for increased understanding of environmental data among their staff and community members. The four organizations—Blue Ridge Environmental Defense League, Pesticide Watch Education Fund, Little Village Environmental Justice Organization, and Toxics Action Center—were named in the proposal for funding Statistics for Action and were active partners during the project. These organizational leaders then designated staff to participate in Statistics for Action professional development. Campaign issues ranged from methyl iodide use in California's strawberry fields to containing the operations of a junkyard in Vermont. A number of issues were on residents' minds:

fumes from an asphalt plant, toxins from a medical waste incinerator and a galvanizing plant, water contamination from a recently closed textile or pesticide manufacturer. Interested readers can find stories and accompanying educational materials in the *Change Agent* issue on Staying Safe in a Toxic World (http://sfa.terc.edu/materials/changeagent.html). Toxics Action Center played a key role early in the project, giving feedback on draft versions of materials. It hired staff with experience in grass-roots organizing, but initially just one had a degree in environmental science. Over time more organizers and organizations were recruited to use SfA materials through project advisors' networks and conferences. The majority were college-educated young women, though organizers ranged in age from 23-60+. They played diverse roles on the project, recruiting community groups for pilot testing, supplying data sets, fleshing out stories, and reviewing materials. They offered feedback after using activities and participated in quarterly conference calls to share best practices. A core group of eleven participated in evaluation activities including surveys before and after being introduced to SfA and annual interviews.

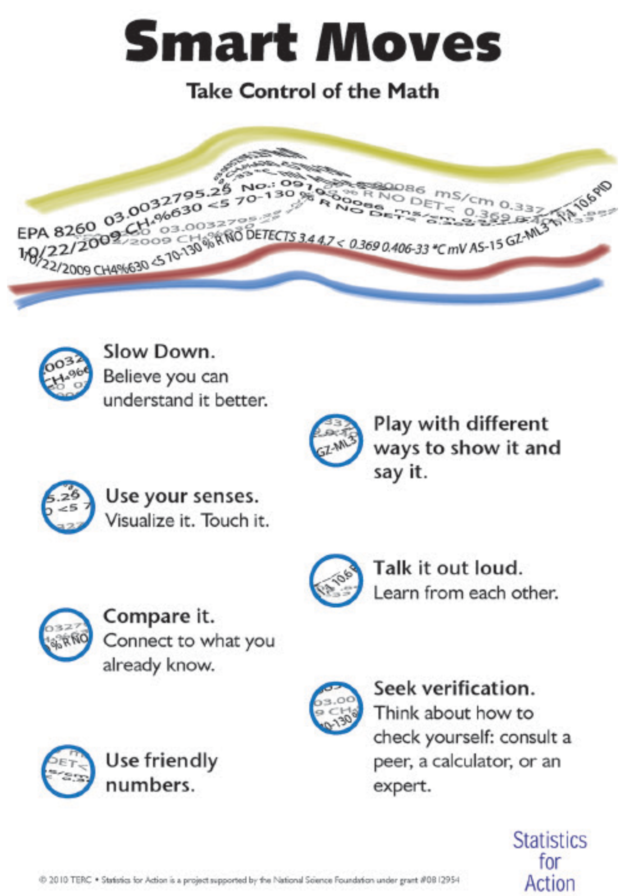
Conditions under which organizers work are challenging. Unlike settings such as museums and nature centers which offer recreation, family-friendly learning opportunities, or entertainment, an environmental campaign asks adults to attend lengthy meetings and to volunteer for unpaid work. Meetings about environmental campaigns can be emotional. Residents are often angry about past wrongs and stressed about future outcomes and current impacts on their health. Meeting agendas may shift at the last minute due to newly released data or a change in hearing dates. Key group members may become ill or move away. In keeping with the characteristics of science and math learning in informal venues, challenges and opportunities arise from the compelling, learner-driven but unpredictable nature of learning opportunities in environmental organizing (Allen and Gutwill 2011).

New Practices for Facilitating STEM Learning: Smart Moves and Memorable Messages

Using the Smart Moves

SfA educators introduced a list of Smart Moves that set group norms when math-reticent or math-phobic participants would be asked to do math during a group meeting that could include mathematically confident peers. An educator with many years of experience drafted the first set of Smart Moves in the project's first year. The Smart Moves were printed on 11"x17" paper and presented as a poster that could hang during a community meeting or workshop. At professional development sessions for environmental organizers in the first two years of the four-year project, SfA educators modeled using the Smart Moves both as ground rules, reviewed before any activities or taxing mathematics, and as facilitation strategies, guiding small group work. On an annual basis SfA's materials were revised and updated. SfA educators reviewed and tweaked the wording of the Smart Moves at these

FIGURE 1.



junctures in order to be in synch with organizers' sensibilities. Smart Moves were popular with several environmental organizers who posted them, read them aloud, or modeled them in their work with community members. During community group meetings and conference sessions, organizers regularly preceded activities on environmental data with a review of the Smart Moves. This practice was not mandated, but rather left to organizers, who generally posted and mentioned the Smart Moves at formal workshops. In meetings in living rooms with fewer than 10 people, explicit references to Smart Moves were less common.

Slow down; Talk it out.

These moves invite exploring the implications of numbers. Even if several members of a group can quickly convert measurements in micrograms to parts per billion, the group should take time, slowing down to make sure everyone follows. In so doing, participants have a chance to absorb the full impact of the quantities. Smart Moves can also be shared in advance with experts, academics, and regulators scheduled to present to community members. When experts, academics, and regulators present to community members, "slow down" reminds them to pause as they rattle off numbers, letting the audience absorb a statistic before stating the next one. "Talk it out" reminds everyone that in this setting people can talk and laugh, work alone or with others, and clarify their thinking by explaining aloud to a peer.

Connect ideas to what people already know; Appeal to the senses; Show numerical relationships in more than one way.

Relating to something familiar is an effective strategy for taking in new information (Willingham 2010) and makes ideas stick. Props as well as tactile experiences make a lasting impression. A Sweet'N Low™ packet conveys the weight of one gram more quickly than words can. A visual aid or physical object grounds understanding of amounts relative to one kilogram (especially handy in the world of milligrams per kilogram). Presenting numerical relationships in more than one way (using raw numbers, percentages, ratios in simplest terms, and approximate fractions as well as analogies and props) invites people who are not so proficient with mental math to visualize the relationships.

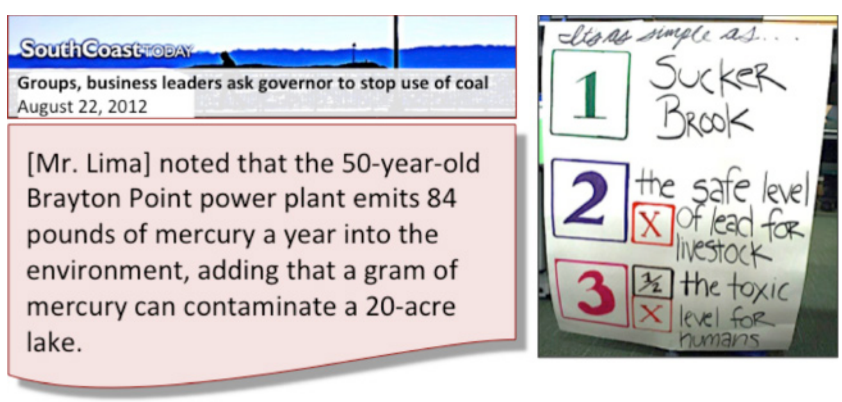
Verify.

Choosing the right level of precision is something community group members talk about as they craft messages. Groups have to be strategic. They base their arguments on numbers from sources such as the Centers for Disease Control, annual reports or press releases from facility owners or proposers, or from an environmental impact statement. The stakes are high; credibility is on the line. If a community group or organizers disseminate information that is subsequently shown to be false, they are discredited and dismissed. The Smart Moves thus include advice to verify claims and findings.

Besides dispelling excuses about not being good at math, the Smart Moves made explicit the expectations for participating in an SfA activity. Smart Moves introduced a way of doing math distinct from the school experience common to most adults, in which silence was expected, dialogue discouraged, and reasoning out a problem with another student was interpreted as cheating. The Smart Moves can be used for problem solving in any domain. Below we explain how they were relevant to environmental organizing. Some organizers quickly adopted the Smart Moves, seeing them as a bridge or transition to activities. One organizer said:

> "Having an environmental studies background doesn't pre-

FIGURE 2.



SouthCoast TODAY

Groups, business leaders ask governor to stop use of coal

August 22, 2012

[Mr. Lima] noted that the 50-year-old Brayton Point power plant emits 84 pounds of mercury a year into the environment, adding that a gram of mercury can contaminate a 20-acre lake.

pare you to be a teacher. As a quasi-teacher, it was very helpful to have the Smart Moves. They were a reminder to the community members of how to tackle the math and science, and taught everyone, including me, very quickly what to do and what not to do."

FIGURE 3. Sample Memorarable Messages — How toxic is dioxin?

The legal limit for dioxin in drinking water is 0.0003 micrograms/L. That's the same as 1 gram of dioxin added to 8.8 billion gallons of water.	1 gram of dioxin is enough to poison the amount of water the average American would use in 15,000 years.
1 gram of dioxin is enough to poison the water that 15,000 Americans use in one year.	1 gram of dioxin would make 8.8 billion gallons of milk unsafe to drink.
1 gram of dioxin would poison 13,333 Olympic sized swimming pools' worth of water.	1 gram of dioxin would make the amount of water used by all of the people of Concord, MA unsafe to drink for a year.
One half-gram of dioxin would poison all the water in Walden Pond.	1 gram of dioxin is enough to make 33 billion liters of soda unsafe to drink.

Messaging Activities

Community groups' main focus is to convince others of the need for action. Finding effective ways to share data on environmental conditions is clearly central to the work. The **Memorable Messages** activity sparks discussions on effective communication. It also encourages slowing down while modeling the use of different numerical representations. For this activity, everyone in the group reads one environmental fact and alternative versions restating that fact. The facilitator asks everyone (in pairs) to speak to the statements: *Which one makes the most powerful impression? Which one is least impressive to you?*

Once organizers facilitated Memorable Messages, they engaged group members in crafting and discussing alternate messages for the local campaign. When confronted with unwieldy quantities or units, one strategy is to scale numbers up and down until one finds a quantity in a unit that is easier to grasp or that uses some familiar element so that the unwieldy quantity makes a strong impression. The next step is to situate these quantities in a context/in a statement that makes it easier for the audience to imagine the impact. Participants stated and restated amounts and relationships, reflecting on the impression that each statement made.

For example, participants restated a fact about emissions from a proposed biomass incinerator. The permit stated that the facility could emit up to 246.8 tons per year of carbon monoxide, nitrogen oxides, and sulfur dioxide. With the population of the host county at hand, the group adjusted time and quantities, generating and critiquing versions of the original fact, such as

- About a pound of carbon monoxide per person in the air all the time.
- Figure out how much CO is in one cigarette. Say it's like smoking X cigarettes.
- Inhaling 0.13 pounds of each of these pollutants per day per person.
- The amount per day works out to one can of toxic soup.
- Imagine the fifteen pounds of carbon monoxide and other chemicals sitting on your head for 365 days a year. That'd have an effect on you!

Participants debated the pros and cons of each statement. One person said 0.13 pounds didn't sound impressive. Fifteen pounds of carbon monoxide was impressive-sounding, but a "can of toxic soup" was easier to visualize. Discussions with attention to quantity, analogies, and scale became a routine part of environmental organizers' work with community groups, often followed by conversations to further refine a statement and verify the claim with an expert.

Discussion

Notes from meetings and calls documented organizers' enthusiasm and efforts as well as their resistance to facilitating certain activities. Among activities that were ignored or rejected were those that needed props, extensive set-up, had accompanying worksheets that organizers deemed elementary in look or content, and those that involved practice without a clear connection to moving the campaign forward. Project partners initiated a set of practices focused on messaging and communication, which were perceived as useful by organizers and participants. When asked for feedback on a short survey, participants in workshops and trainings were positive and confirmed the potential impact of the SfA resources. Of the 187 surveys collected in the project's final year, ninety percent of participants agreed that doing an SfA activity gave them more confidence to speak about the topic; sixty percent (n=183) felt confident in understanding the issue after the activity compared with twenty-eight percent before (Connors et al. 2013).

Organizers persuaded STEM educators that activity names and goals had to have a mission-based, campaign-focused objective. SfA's educators worked to convince organizers that examining and incorporating data could strengthen the points that organizers were hoping to make through stories. In fact sheets, testimony, press releases, *and* in-person conversations, community members needed to weave numbers and stories into their communications. A community organizer commented on her transformation: "I tended to gloss over these issues before because they overwhelmed community members. Now I have a set of tools to address sorting out numbers, messaging, figuring out how to make sense of data and communicate risk."

Collaboration resulted in more conscious, intentional use of data during meetings, leading community members to listen for sound bites they would use in communicating with others on environmental topics. The project's external evaluators found that adding facilitating science and math learning to their repertoire of assistance to community groups was doable but not trivial for organizers. See Arbor Consulting Partners *Evaluation of Statistics for Action Final Report* (Connors et al. 2013) for more detail. There is much work to be done to understand who gets up to speed and how. We concur with Lemke et al. (2015), who call for assessment strategies that could capture know-how and know-who as well as know-that. Assessment should examine evidence that knowledge is being used and that this use persists, grows, and cumulates over relatively long periods.

Conclusion

Working alongside environmental organizations can have a huge payoff for STEM educators interested in reaching underserved audiences, including rural and inner city residents with limited formal education. Though community members may expect that educators will do all the math and understanding *for* them, the opportunities for collaborative teaching and learning are authentic, as all group members have relevant experience or knowledge to contribute, even though most do not have technical expertise or formal education in environmental science.

SfA was founded on the premise that *all* group members can contribute to the scientific and mathematical aspects of the work involved in environmental organizing. From its inception, the project has sought ways to expand the number of individuals investigating the math and science from one or two to the wider group. Smart Moves were a tangible signal that everyone could step onto the playing field. Our experience is that certain practices and approaches are a useful starting point for collaborations centered on environmental campaigns. SfA activities and resources are free and online (sfa.terc.edu), available to support environmental organizers who want to facilitate math and science understanding. The materials are relevant for educators and others interested in using environmental data sets in the classroom. Each activity includes a facilitators' sheet with information like the skills addressed, suggestions for launching and debriefing the activity, and hints for preparation, as well as the most salient Smart Moves.

Organizers' role in this transformative work is critical. We leave the last word to an organizer who benefitted from approaches generated by the SfA collaboration of organizers and STEM educators.

> *My general orientation before this project was that those sorts of fact and figures—we don't really want to tell those in our story, people don't understand them, we don't have the tools to understand them....*
>
> *I've had a small but fundamental shift in my orientation in thinking about and telling the stories of the campaign that we're working on.... I think that in general, figuring out how to describe problems and solutions when it comes to pollution and environmental health using numbers and coming up with powerful messages and powerful details to help flesh out the story is helpful for campaigns (Connors et al. 2013).*

About the Authors

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PROJECT REPORT

Incorporating Photo-Book of Concepts in Physics and Environmental Chemistry Courses

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Abstract

Much has been written about the importance of helping students gain critical thinking and analytical reasoning skills that are transferable beyond classroom situations (Association of American Colleges and Universities 2007; Kuh 2008). Student engagement correlates positively to these skills as well (Carini et al. 2006). To this end, the photo-book activity was designed to allow students opportunities to connect real-world applications with course concepts. By analyzing the relationship of the subject matter to the real world, students reinforce their understanding and application of ideas learned in class. In the photo-book project, students were asked to capture class concepts in pictures. This assignment encouraged students to be more observant and to search for examples in their world and further allowed them to freely express their interpretation of the subject and reflect on their learning. This project was embedded in various classes (as recommended by Pithers and Soden 2000) such as physics, environmental chemistry, and climate change, and also in community projects such as Earth Week. In this paper we discuss the details of the photo-book concept, offer examples of students' comments, and finally, present an overview of this learning model.

Introduction

Critical thinking and analytical reasoning, problem-solving skills, and the ability to understand varying perspectives on issues are among the traits valued by employers in evaluating job applicants. As knowledge is expanding so quickly, students cannot possibly master content knowledge; the key is to learn habits of mind that will enable them to continue learning beyond their formal academic training. Experiential learning activities can help students integrate and apply skills and knowledge in real-world settings and situations, and thus accelerate their success (Association of American Colleges and Universities 2007; Kuh 2008; Texas Woman's University 2013). Furthermore, student engagement is positively linked to learning outcomes such as critical thinking and grades (Carini et al. 2006). Extensive research also suggests that students need to "think well," and activities should be embedded in courses to encourage critical thinking (Pithers and Soden 2000 and references therein).

Texas Woman's University (TWU) founders recognized the importance of this and adopted the University motto, "We learn to do by doing." Stemming from a quote by Comenius (considered the father of modern education) and recommended by Helen Stoddard, one of TWU's first Regents, the motto captures the unique focus of a TWU education so well that it was engraved on the University's first building (Bridges 2001, 7).

At TWU, experiential learning may include internships, service learning projects, civic engagement, scholarship, or creative activities. Creative activities include projects that provide students with real-life, hands-on experiences. Engaging students in creative activity reinforces academic knowledge and establishes a foundation for academic growth. Student experiences may extend beyond the classroom. The photo-book project described in this paper is one such creative activity. Universities are increasingly incorporating such opportunities into the curriculum and institutional offerings (Karukstis 2010; Lopatto 2010; Malachowski and Dwyer 2011; Sheardy 2010; Sloane 2010). Thiry et al. (2011) note, "Undergraduate science education should be augmented by student engagement in high quality, 'real world' experiences that meet students' broad range of interests, talents, and career goals. Well-designed experiences supplement classroom learning in many ways…" (384). Asking students to contextualize what they are learning in class should be expected to inspire motivation (Fisher 2016). Understanding how our students are motivated and finding practical strategies can improve the quality of learning in our courses (Ambrose et al. 2010). Eyler (2009) suggests the benefits include "a deeper understanding of subject matter than is possible through classroom study alone; the capacity for critical thinking and application of knowledge in complex or ambiguous situations" (26). Such activities provide a means to both enhance student engagement and to better prepare students for success after graduation.

TWU's Quality Enhancement Plan (QEP), *Pioneering Pathways: Learn by Doing*, is a five-year plan mandated by our accrediting agency. It is designed to enhance student learning through student engagement in experiential learning.

The intention of this project is expressed in the words of Benjamin Franklin, "Tell me and I forget, Teach me and I remember, Involve me and I will learn." Learning by doing and applying theory to practice is considered crucial for student success in an ever-changing, increasingly connected, and global world. The related QEP Student Learning Outcome (SLO) for our photo-book activity is for students to *effectively connect classroom theories to real-world experiences through practical application of knowledge*. In this paper we discuss three QEP-designated courses and how this SLO was addressed using the photo-book of concepts in each course.

Beginning in the summer of 2007, faculty at TWU engaged with the SENCER community of practitioners to improve science education. SENCER focuses on real-world problems and, by so doing, extends the impact of this learning across the curriculum to the broader community and society. Faculty develop expertise in teaching "to" basic, canonical science and mathematics "through" complex, capacious, often unsolved problems of civic consequence. Using materials, assessment instruments, and research developed through SENCER, faculty members design curricular projects that connect science learning to real-world challenges (Middlecamp 2011; Sheardy 2010; Sheardy and Burns 2012). The SENCER understanding of learning acknowledges a debt to the philosopher William James, who wrote in his *Talks to Teachers* (1899):

> *Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. The two associated objects grow, as it were, together: the interesting portion sheds its quality over the whole; and thus things not interesting in their own right borrow an interest which becomes as real and as strong as that of any natively interesting thing. The odd circumstance is that the borrowing does not impoverish the source, the objects taken together being more interesting, perhaps, than the originally interesting portion was by itself.*

More contemporaneously, SENCER's work is informed by the National Academies' commissioned reports on learning, notably *How People Learn and Knowing What Students Know: The Science and Design of Educational Assessment* (Bransford et al. 2000; Pellegrino et al. 2001). SENCER Ideals have been applied to develop field-tested courses for many disciplines on a broad range of topics. Among those ideals, "SENCER conceives the intellectual project as practical and engaged from the start, as opposed to science education models that view the mind as a kind of storage shed where abstract knowledge may be secreted for vague potential uses." Students and faculty report that the SENCER approach makes science more real, accessible, useful, and civically important (Carroll 2012).

We are introducing a creative activity we call photo-book of concepts included in three courses (physics, environmental chemistry, and climate change) at TWU. Each is a QEP-designated course at TWU; each is also a SENCER course. Maguire's environmental chemistry course was, in fact, our first SENCERized course.

Photo-Book of Concepts

The photo-book project described here is an example of a learning activity which also includes the guided reflection concept. We teach students the laws and concepts of the subject matter in the classroom. Then students have a chance to independently think about what they have learned in the class and look around for illustrations of the concepts in their everyday lives. This activity encourages students to be more observant and search for examples in their world. This assignment allows them to freely express their interpretation of the subject and reflect on their learning. In this project students are required to take a few photographs (four to six) that represent the ideas in the subject matter. Students need to email two of their pictures to the instructor, each on a single slide in a presentation file format, along with a title and a description of what concept each picture represents. (See Figures 2, 5 and 6 for examples.) The instructor gives feedback to help students focus on successful ways of thinking about the assignment. After receiving the comments back from the instructor, final pictures in the same format are sent to the instructor along with their titles and descriptions. The instructor then chooses one picture from each student to exhibit on the wall of the classroom. At the exhibition, each student selects one picture (not their own) they find interesting and writes a reflective paragraph on why the photo grabbed their attention and how it relates to the subject matter. Finally, for a larger class the instructor chooses 15-20 representative pictures (the number is up to the instructor) that show different concepts in the course for printing on a poster. This poster could be displayed in the department and might even be presented in a larger scale on the campus or at conferences. For a smaller class, the instructor could divide students into groups and ask each group to make a poster presentation. More detailed instructions, examples of timelines, and detailed rubrics are included as an appendix to this article.

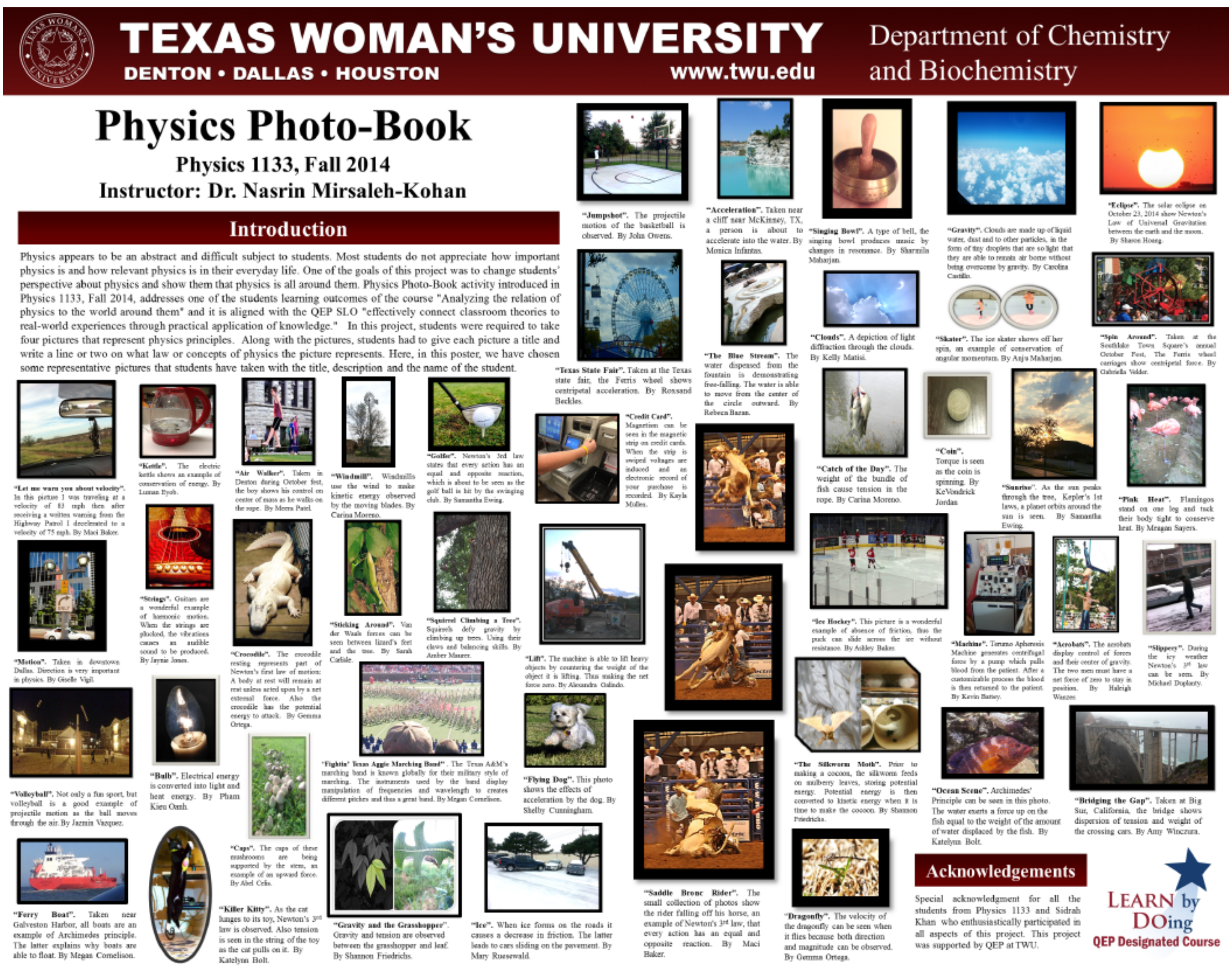
Physics

Physics appears to be an abstract and difficult subject to most students, especially if their major is not physics. Most students do not appreciate how important physics is and how relevant it is in their daily lives. The photo-book activity is a unique bridge between explaining physics concepts in a classroom and observing them in the real world. This activity was included for the first time in the algebra-based physics course in fall 2014, addressing one of the course SLOs, *analyzing the relation of physics to the world around them*. This activity was also aligned with the QEP SLO, *effectively connecting classroom theories to real-world experiences through practical application of knowledge*. There were seventy-five students enrolled in this class. As part of the class, students were assigned to start looking more carefully around them in search of physics and to capture physics principles in pictures or photographs. The idea behind this project was to change students' perspectives about physics. This activity required students to take four photographs (just to have a manageable number of pictures due to the large number of students) that represented physics principles. Pictures had to be photographs students captured personally (pictures taken online or from other sources were NOT accepted). For instance, they could take a picture of ice on a plant's leaves. This picture can represent the heat concept in physics and how water needs to be 0° Celsius to become ice. This assignment made them look at their world carefully, reflect on what they learned in the class and find physics. As they started to develop an awareness of physics more and more, the instructor hoped they would want to learn more. Students had to email two of their pictures in a presentation file to the instructor to receive preliminary feedback on their pictures. A few weeks later, they submitted all four pictures. The instructor chose one picture of the four from each student to exhibit on the wall of the physics laboratory so that all the students could see their classmates' work. At the exhibition, each student selected a photo that she thought perfectly showed physics and wrote a reflective paragraph about it. Since the students were asked to focus on just one picture, they were able to think about one physics concept more deeply and reflect their understanding in a written format. It was very interesting to read different students' reflections about the same picture, and see how each student emphasized something completely different. For example, when we see a picture of an ice skater, we might see the concept of motion and Newton's second law in the picture. However, there is also conservation of angular momentum in the motion of an ice skater. When ice skaters close their arms, they will spin faster. Furthermore, reflective writings also revealed students' misunderstanding about a concept. Overall, displaying the pictures on the wall gave students an opportunity to share their experiences. Finally, we chose about forty-five most representative pictures showing different areas such as nature, chemistry, biology, and music and made a poster. This poster (shown in Figure 1) is displayed on the wall outside of the physics lab and was also presented at several university events (e.g. in the experiential learning showcase and at the Celebration of Science symposium at TWU). This poster was also presented at the 2015 SENCER Summer Institute in Worcester, MA. Moreover, presenting this poster to other students who were not taking physics sparked an interest in them and showed them physics in new places. This activity was also incorporated in the algebra-based physics course for fall 2015 and we will continue to include this project annually in physics classes.

Environmental Chemistry

TWU students enrolled in environmental chemistry during the spring 2014 semester were assigned to collect a series of eight photographs related to water issues, and the class will select the best for inclusion in posters to

FIGURE 1. An example of one of the posters made in the physics course.



be displayed during Earth Week (April 21–25). Figure 2 shows an example slide illustrating the assignment, which was submitted as a presentation file with one photo per slide. Students were encouraged to take their own photos, but were also allowed to use photos found online in cases where they needed material that is not available locally in north Texas (e.g. ocean garbage patch, etc.). Several opportunities for photography were offered during field trips to various places in and around our community. After all the photos were collected, they were printed on copy paper and displayed on a large wall during one class period. Students then worked in small groups of two or three to collect the best examples related to their particular water issue.

FIGURE 2. An example slide illustrating the assignment, which was submitted as a PowerPoint file with one photo per slide.

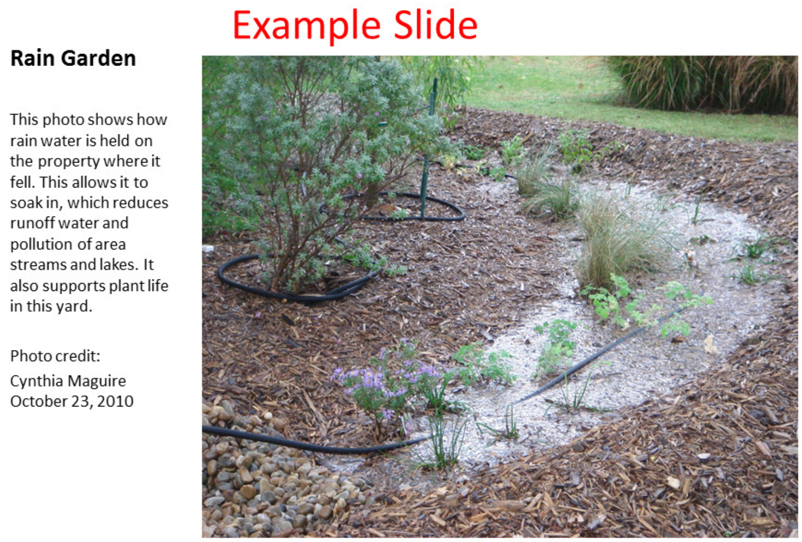
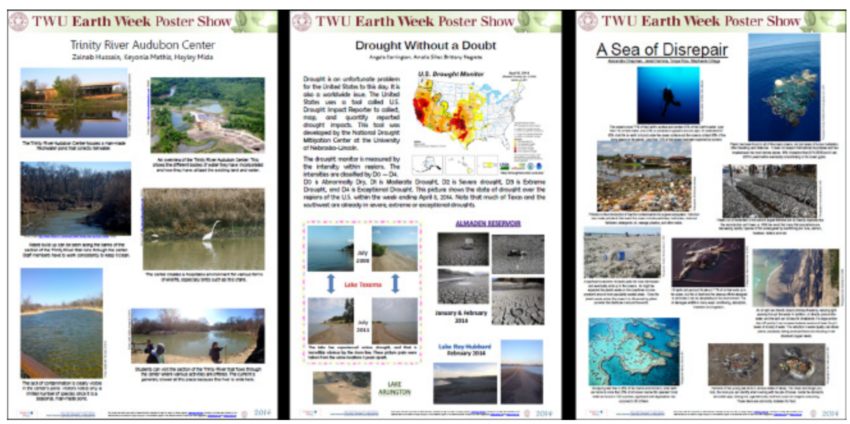


FIGURE 3. Selected water photo posters exhibited during the Earth Week poster show.



Earth Week Poster Show

Once each group had selected appropriate photos, environmental chemistry students were instructed to tell their water photo story in pictures with minimal words as captions for the photos. Their assignment included making the information understandable for elementary school children who would be attending the reception held during the Earth Week exhibition. A grading rubric (see appendix) was devised for this assignment prioritizing content, organization, and grammar. Selected water photo posters are shown in Figure 3.

Children in some area elementary schools were also invited to create posters and the best were chosen by a group of their faculty to be included in the TWU Earth Week exhibition. One of the instructor's goals in organizing this QEP- and SENCER-sponsored event was to increase the desire to attend college among school children participating, and to enhance their perception of TWU as a prospective institution to attend. The students and their families and teachers were all invited to the reception held on campus during the exhibition. The reception provided a time to share between the younger students and TWU environmental chemistry students. Selected children's posters are shown in Figure 4. In addition, organizing the exhibition provided an experiential learning opportunity for two elementary education majors taking the environmental chemistry course.

Climate Change

The Climate Change class in spring 2016 was assigned to take their own photos of climate change in the world around them. Their instructions were, "Photographs must be your own original work. They cannot show people's

FIGURE 4. Selected children's posters created by children in area elementary schools and exhibited at TWU's Earth Week poster show.

faces and cannot include children. Each photograph must be in a common image format such as JPG or TIFF, and at least 1.0 MB file size in order to have adequate resolution if printed." Images were uploaded into the course Blackboard along with a descriptive paragraph to explain the image connection to climate change, as a portion of the credit for the midterm exams. The instructor (Maguire) failed to require use of a presentation file format for submissions, which led to increased difficulty correlating descriptions with photos.

Consistent with the creativity shown in the physics and environmental chemistry courses, students in Climate Change were able to see impacts of changing climatic conditions in ordinary things around them. Photos included large hailstones from an unexpected and dramatic hail event in Fort Worth, a tree entangled in power lines, and an adult butterfly photographed in early January—unusual even for north Texas. A selection of photos and reflective writing descriptions are shown in Figure 5. Students were able to articulate that excessive precipitation, hailstorms, drought, technology impacts, and biological cycles outside of their usual timing were all perceivable manifestations of climate change. Maguire plans to create a climate change photo poster to promote the course on campus and to use when presenting the photo-book idea.

Assessment

We have employed direct and indirect assessments to measure students' learning in this project. In the direct assessment, we used students' photos to evaluate their understanding of the concepts presented in the pictures. The student learning objective for our QEP-designated courses was to *effectively connect classroom theories to real-world experiences through practical application of knowledge*. The photo-book assignment was used to measure this objective in all courses mentioned in this article. Grades on the photo-book of concepts tend to be higher than other coursework, indicating that students are able to connect classroom theories to real-world experiences, and that this activity was an effective tool in helping students achieve that connection. We have attempted to compare overall course averages using this assignment with classes that did not utilize the photo-book. Unfortunately, it is not possible to make a direct comparison because one of us was not teaching at TWU prior to using this assignment and the other made more than one change in her course design. No assessment data are available for the climate change course as it was still in progress when this article was written.

Indirect assessment of students' learning took place during the in-class picture exposition while students were sharing their ideas about other students' photos and also in a reflective writing piece that they submitted later. (See an example in Figure 6.) Moreover, students' comments in the course evaluations have demonstrated that this is an engaging activity for the students and further expands their understanding and appreciation of the subject matter. Unexpectedly, this project also leads students to learn more about their peers outside of class. Some students are passionate about rodeos, have traveled to exotic places, or have unique hobbies. In this experiential learning activity, students were more observant and searched for examples of the subject matter in their world. This assignment also allowed them to freely express their interpretation of the subject and reflect on their learning.

From course evaluation comments it is clear this activity was one of the students' favorites. They were also surprised how much they had "learned by doing." Here are a few of our students' comments as written in the physics class evaluation forms:

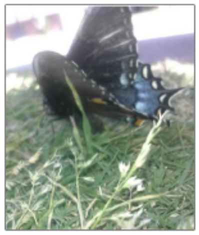
FIGURE 5A-C. A selection of photos and reflective writing descriptions submitted by students in the climate change course.

Out of sync

This photo shows....

I was able to take this image during the winter break and there are many details here that we can link to climate change. As we experienced every year is different, we have hotter winters and there are animals we encounter on campus when they should be hibernating. This picture is a perfect example because we can see the sunlight in the background and a butterfly. The climate Texas is adopting is changing the habitat of many animals, they have to come out in the winter for food or for survival. Something that years ago was not normal to see, now we see it as something that happens almost every winter. This is dangerous because it's interrupting our environment and if this keeps its pace then we might lose some of our species around the world. Species that we need to survive and have a stable ecosystem.

Date: 1/02/2016
Time: Noon
Place: Front yard of my house/ Dallas Tx

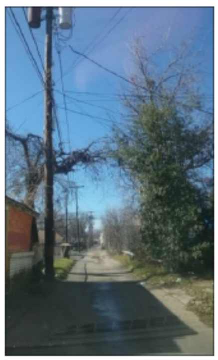


Trees vs. Technology

This photo shows....

There are many things going on around us that may seem important, the new iPhone, or new technology getting built. But we don't stop and think of the things that really matter around us, those things are changing and they are changing our environment. In the image above I was able to stop for a couple of minutes and contemplate about how technology is taking over our environment and more important how it's changing our climate. The image shows an electric pole head to head with a tree, but we can easily see that they are fighting for a "spot." The [branch] of the tree is trying to enforce its leaves over the cables but it is impossible for the environment to win on this one. It is impossible for the environment to be stable in a place where new technology is the most important thing. There is a collapse between the tree and the wires and we all know who is going to stay in the spot. It will be difficult for many to understand that climate change is affecting the trees like this one.

Date 03/12/2016
Time: 4 pm
Place: Street in Dallas TX



Wet and dry years

This photo shows....

This photo of a tree signifies climate change because of the different ridges in the bark. A tree can tell us how old it is and how much water was available each year. This tree has a variety of healthy and unhealthy rings. We can see that the tree was at its healthiest during its younger years, because of the lighter rings. The darker rings expose the drier days which the tree experienced.

Date: March 14, 2016
Time: 5:40 p.m.
Place: TWU golf course

- "The photo-book project, it was actually pretty interesting paying attention to a world filled with physics."
- "This course forces you to apply the concepts that you learn to things in your everyday life."
- "The teacher really shows that she cares and wants to work with us. I am very glad the homework allows multiple attempts because it helps me get through the thinking [process] no matter how long it takes. I enjoyed the Photo Book project."
- "The photo-book project was exciting and a fun way to learn the practical application of physics."
- "Being shown how we could really apply what was being taught in real life situations."
- From their comments, it is clear that the photo-book assignment led students to "think well" and critically, as Pithers and Soden (2000) predicted.

FIGURE 6. An example of a reflective writing piece; one student wrote this paragraph about another student's photo. The student who took the photo saw equilibrium. This student saw potential energy in this picture. Both concepts apply to this scene.

Atop the Telephone Pole

I picked photo #4, which is of a girl standing on a pole with safety harnesses attached to her. I chose this picture because I thought it looked the coolest from all the other pictures that were taken. This photo relates to physics in a number of ways. The first relation to physics that I noticed was potential energy. Potential energy is the stored energy of position possessed by an object. If she were to lean a little in either direction, it would cause her to be off balance and force her off the pole exerting energy. A second relation to physics I noticed was that there was tension on the safety harness that was keeping her from falling. Tension is the force that is transmitted through a string, rope, cable, or wire when it is pulled tight by forces along the length of the wire and pulls equally on the objects on the opposite ends of the wire.

One of the authors (Maguire) noticed when she included this project for Earth Week in her class she received one of the highest-ever course evaluation ratings from the students in that class; she has taught the course every semester since fall 2007. This higher rating might possibly be attributed to student motivation being higher since this project was a practical strategy to connect class concepts to students' interests (Ambrose et al. 2010); also, the students discovered how relevant these ideas are to the world around them, a key part of learning to analyze and innovate ideas (Association of American Colleges and Universities 2007).

Interestingly, a student's submitted photo can also give valuable insights into their understanding or misunderstanding of the concept they are trying to portray. One such example (Figure 5c) was a tree trunk with a large limb sawed off. The student stated that the image "signifies climate change because of the different ridges in the bark." This provided an unexpected opportunity for faculty to clear up a misunderstanding.

The SENCER Student Assessment of Learning Gains (SALG, www.salgsite.org) allows students to rate how well specific activities help their learning. SALG data from five years (2007 to 2011) and more than 1300 instruments evaluating SENCER courses have indicated that this type of pedagogical approach enhances durable learning and a deeper understanding. Carroll (2012) reported that SENCER faculty are making more progress toward the main categories of pedagogical goals—those related to (a) understanding course content, (b) skill-building, (c) changing attitudes toward science, and (d) building habits of mind and behavior—than their non-SENCER colleagues. These surveys constitute about twenty-seven percent of the total SALG course evaluations in that period of time. Although we have not used SALG to evaluate the photo-book assignment, based on the reflective writing our students have done we expect that our students have acquired a deeper understanding and durable learning from this activity.

Conclusion

We developed the photo-book project as a creative learning activity in our courses to provide an opportunity for our students to develop a deeper understanding of the subject matter in our courses. We also wanted students to learn how relevant science subjects are to their everyday lives. After incorporating this project in various sections of three courses and one community outreach event, we believe the photo-book of concepts idea is a valuable tool for students and instructors alike. Our future plans include the use of the the photo-book assignment in courses we teach regularly and additional assessment through both our QEP program and the online SALG. Photo-books have great potential in terms of students' developing enduring learning, but they are also a manageable workload for faculty. The project has been successfully completed twice in physics classes, and once each in environmental chemistry and climate change. After additional experience, we may choose to make the photo-book assignment an embedded assessment tool.

This project can be employed in larger or small classes. The physics class had seventy-five students, while environmental chemistry had twenty-two and climate change had only ten. Varying the number of photos submitted (four in physics versus eight in environmental chemistry) made it easy to adjust the workload. The project does not require any specific device or equipment; students only need a camera, and most of our students have been using their cell phones. It is essential to have a practical way of dealing with large file sizes. We have accomplished this using submission via email to a special email account (e.g., physphotobook@gmail.com) or uploading into Blackboard, either into a Discussion Board (visible to all students) or as a graded assignment link that was not shared with other students. All processes worked well provided students were required to place each photo and the accompanying text on a presentation slide for submission. This is necessary in order to keep it practicable. Other tools such as cloud sharing of files are available as well. In any case, faculty need to be sure that their selection fits the technology limitations of their situation.

In this assignment we seek to help students understand the subject through connecting it to interests already in their daily life. For example, a student who attends a rodeo to watch a family member compete takes pictures of a rodeo event and connects the rodeo to physics. Such a student could be more interested in physics in the way William James (1899) stated, "Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists."

Posters and oral presentations resulting from the photo-book activity have been shared during various meetings and symposia, both on and outside our campus. Faculty members in a wide variety of disciplines have shown an interest in this idea and have asked for our instructions, leading us to write this article in order to share our experiential model with a wider group of educators. We believe the photo-book of concepts will be a positive experience in whatever disciplines it may be applied.

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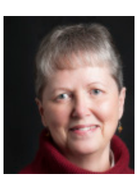
About the Authors

Nasrin Mirsaleh-Kohan received her Bachelor of Science degree in Physics at the University of Tehran. She came to the U.S. as a graduate student and earned her Master's degree in computational Physics at the Bowling Green State University. In 2008, she finished her Ph.D. in Physics from the University of Tennessee (UT), followed by a postdoctoral fellowship at the University of Sherbrooke in Canada. Then she returned to Tennessee and was a postdoctoral research associate at UT. Kohan accepted her first tenure-track faculty position at Texas Woman's University (TWU), Department of Chemistry and Biochemistry in May of 2013. She teaches algebra-based physics and calculus-based physics. Her research interests include surface-enhanced Raman scattering, interaction of anticancer drugs with DNA, negative ions, and radiation damage to DNA.

Nasrin is already a strong believer in using hands-on experiences to educate students. She is excited to have found a place that values her creative approach to teaching physics, as evidenced by her selection as a TWU Experiential Learning Fellow.

Kohan is co-advisor for the KEM Club (Kappa Epsilon Mu), TWU's student chapter of the American Chemical Society. She has incorporated various civic engagement activities in KEM club such as the Thanksgiving food drive and Calculate it Forward. Nasrin is also part of the SCI-Southwest team at TWU and helps to convey the mission of SENCER in the Southwest region.



Cynthia Maguire earned her B.S. from Central State University in Oklahoma and two M.S. degrees--biology teaching and chemistry teaching, both from Texas Woman's University. She remained at TWU and is now a Senior Lecturer in the Chemistry and Biochemistry department.

Ms. Maguire created the first SENCER course at TWU, Introduction to Environmental Chemistry: Global Perspectives, in the fall of 2007. She teaches primarily sustainability-related courses which form the core of an upper-division certificate program, Science Society and Sustainability. Cynthia is faculty advisor for Roots, a student sustainability organization at TWU; and she models civic engagement for her students through her leadership in the Native Plant Society of Texas, helping students be aware of sustainable, water- and habitat-conserving landscaping on their property and in their communities.

Maguire is also working on the SENCER dual poster project, researching how students learn to communicate disciplinary knowledge to others outside their specialty. Ms. Maguire is co-director of SCI-Southwest and is a SENCER Leadership Fellow. She was recently named a TWU Senior Experiential Learning Fellow. Her work has been published as a chapter in two ACS Symposium books about SENCER, and an article in The International Journal of Sustainability Education.

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Appendix

The following instructions for the photo-book concepts have been designed for the physics classes; however other instructors could modify the instructions as appropriate.

- In this project, students are required to take four to six photographs (depending on the size of the class) that represent the principles of the subject matter. For instance, in a physics class students could take a picture of a merry–go–round and present it as an example of the centripetal force application. Some of the instructions given to the students are as follows:
    - Pictures must be students' original pictures (pictures taken online or from other sources are NOT accepted).
    - Pictures should not include faces, especially children.
    - Students need to make sure they have permission when they take pictures of private properties.
    - Students need to email two of their pictures in a PowerPoint presentation to the instructor by a specific deadline to receive feedback on the pictures. In this PowerPoint, along with the pictures, they need to give each picture a title and write a caption describing the law or concepts of the subject matter the picture represents. It is also more convenient if the students title their PowerPoint presentation using their last name and first name (e.g., if John Smith is submitting the PowerPoint, the name of the file should be Smith_John). It is advised that the instructor (or TA) of the class create a separate email account since these files tend to be large and could fill up a personal inbox. The instructor can also ask students to use Blackboard or other tools (e.g., DropBox) to upload their pictures.
- All the pictures (could include the two pictures they have already submitted) should be sent to the instructor by a specific deadline along with their titles and descriptions.
- The instructor will then choose one picture from each student and will exhibit the pictures on the wall of the classroom (or anywhere that is convenient) on a specific day. You might remove the name of the students and just number them so that students would not know whose pictures they are discussing.
- After the exhibition, each student needs to choose one picture (not their own) that has attracted their attention and write a reflective paragraph on why the photo grabbed their attention and the relevance of the photo to a law/principle of the subject matter. The due date for this short paragraph could be a week after the exhibition.
- Finally, for a larger class the instructor will choose 15-20 representative pictures (the number is left to the discretion of the instructor) that show different areas and concepts in the course and print them on a poster. This poster could be displayed in the department and might even be presented in a larger scale on the campus or at conferences. For a smaller class, the instructor could divide students into groups and ask each group to make a poster presentation.

Physics photo-book assignment timeline		
	Due Date	Note
Submission of two photos	Week 7	Two photos along with titles and descriptions to receive feedback
Submission of final photos	Week 10	
Photo exhibition	Week 11	One picture chosen from each student exhibited on the wall of the physics laboratory
Reflective paragraph	Week 12	
Poster Presentation	Week 14	poster. (See Figure 1.)

Appendix

Environmental chemistry water poster assignment timeline		
	Due Date	Note
Submit eight photos	Week 5	
Preview in class	Week 6	Students selected their favorite images and organized them into topical groups in order to create posters
Water posters	Week 10	Each group created a poster
Poster presentation	Week 14	TWU Symposium

Physics photo-book rubric This assignment counted for 5% of the total grade in the class.		
Criteria	Weight	Note
Content	65%	Photos, titles, and descriptions are related to the class concepts.
Reflective paragraph	15%	Clearly describing the relevance of the photo (exhibited in the class) to a law/principle of the subject matter.
Format	10%	As described in the instruction.
On-time submission	10%	

Environmental chemistry water poster rubric The water poster counted for 5% of the total grade in the class.			
Criteria	Novice	Competent	Proficient
Content Weight 60%	25% Thoughts are poorly expressed. Photos may not relate well to theme of poster.	60% Ideas are clearly written. Photos relate to topic. There may not be a seamless connection between them.	100% Ideas and photos are focused on the topic and tell a story seamlessly. Clear communication of essential idea(s).
Format/organization Weight 20%	25% Poor use of space. Difficulty achieving an eye-appealing format.	60% Not all space is used well, but items are laid out reasonably well. Everything needed is present.	100% Space is used effectively. All parts of the poster are complete, and presentation is attractive to the eye.
Grammar/Typos Weight 20%	25% Several errors in spelling and/or punctuation. Difficult to understand what is intended.	60% One or two errors in spelling, but still communicates ideas clearly.	100% No errors in spelling or punctuation.

PROJECT REPORT

The "Muddy Waters" Environmental Geology Course

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Abstract

Teaching geology and its relevance in urban environments is often challenging. "Muddy Waters," a First-Year Experience course for non-majors, uses the concepts of water quality and quantity in an urban environment to introduce current urban environmental geology issues including flooding, wastewater treatment and disposal, and drinking water supply and treatment. Through extensive fieldwork and laboratory work, students investigate these concepts through various extended projects using different themes and then present their results to a variety of audiences. The course utilizes the extensive river and canal system in the Chicago area and topics of current interest to engage learners in the environmental geology that may go unnoticed by the majority of our urban students. Results show that students become more aware of where their drinking water comes from, what happens to wastewater, the severity and frequency of flooding, and engineering techniques implemented to lessen the impacts of flooding in surrounding neighborhoods.

Introduction

Connecting urban students to the geological aspects of their environment can be challenging—more or less so, depending on the geographic setting. In the geologically "plain" setting of Chicago, where there are few visual indicators of geology, students generally lack awareness of, and therefore interest in, the natural processes that shaped their environment. Add to this a public school system that only rarely offers high school earth science courses, and the result is geologically and in turn environmentally disconnected students. At Northeastern Illinois University (NEIU), in northern Chicago, this disconnect from the physical environment may be compounded by student demographics. Nearly 50 percent of incoming freshman are Hispanic, a population traditionally underrepresented in geology and STEM disciplines. About fifty-three percent are first-generation college students. Most do not have role models who have been exposed to the existence, importance, or relevance of career opportunities within the geosciences or STEM and therefore do not readily choose Earth Science as a major (see Table 1.)

TABLE 1. Total Enrollments and Bachelor Degrees Conferred at NEIU (Number of Students)

		Total Undergraduate Enrollment		Bachelor's Degrees Conferred	
		University	Earth Science Majors	University	Earth Science Majors
2011-2012	White	4566	31	839	2
	Black	1156	2	147	0
	Hispanic	3526	11	428	0
	Asian/ Pacific Islander	1098	3	157	0
	Amer Indian/AK Native	27	1	7	0
	First-Generation College	5167	26	NA	NA
2012-2013	White	4358	29	778	4
	Black	1186	2	157	0
	Hispanic	3614	18	404	0
	Asian/ Pacific Islander	1078	4	168	0
	Amer Indian/AK Native	23	1	3	0
	First-Generation College	5715	33	NA	NA
2013-2014	White	4018	24	796	5
	Black	1121	2	149	0
	Hispanic	3590	18	420	1
	Asian/ Pacific Islander	1071	3	184	2
	Amer Indian/AK Native	25	0	2	0
	First-Generation College	5906	31	NA	NA
2014-2015	White	3659	24	796	5
	Black	1050	3	143	0
	Hispanic	3510	19	446	4
	Asian/ Pacific Islander	1035	1	165	0
	Amer Indian/AK Native	24	0	3	0
	First-Generation College	5542	33	NA	NA

We attempted to address these issues by creating and implementing a First-Year Experience (FYE) Program course titled *Muddy Waters: Chicago's Environmental Geology* (ESCI 109W). Like all courses in our FYE Program, the course integrates discipline-specific content (e.g. urban environmental geology) with college success skills (e.g. time management). Discipline-specific content of Muddy Waters focuses on water quality and quantity issues that are timely and relevant in a city where rivers and lakes are key features. Using themes of water quality and quantity, we developed field and laboratory activities designed to build a sense of connection to the Chicago area while addressing current and relevant environmental issues. The course involves extensive hands-on experiences highlighting human impact in an urban environment connected to geology. All class projects are set in the Chicago area, primarily the local neighborhood; field activities, laboratory work, and collection and interpretation of online data address specific content-related areas of interest.

Course Design

We designed the course to provide students with a sense of how urban environmental geology is relevant to their lives and to the city in which they live. Given the diverse makeup of first-year students at NEIU, course elements also aim to increase diversity within the geosciences and STEM disciplines. Through the design and delivery of the course, we strive to help students understand that a career in geology is a legitimate, relevant, exciting, accessible, and attainable goal.

Specific course objectives are that students will learn to do the following:

1. Compile an organized record of data and supporting information from various sources (field, laboratory, class presentations, readings, research), optimized for the student's individual learning style.
2. Distinguish landscape changes effected by stream, lake, and coastal processes; critically analyze patterns of change in water bodies to predict continuing/ future changes.
3. Evaluate the impact of geologic factors on human activities in Chicago (water and waste management, stormwater and sewage treatment/control, construction, etc.) and the effect of human activities on analyzed parameters of water quality and quantity.
4. Apply identified strategies to maximize student achievement of short-term and long-term academic goals through self-knowledge, navigating the university environment, and effective planning.

Here we present the course structure, highlighting activities designed to achieve the course objectives and goals.

Course Projects

The course is structured around five main projects through which students engage in learning activities that provide them with exposure to relevant geological issues and opportunities to learn content and skills and to practice applying what they learn as they work to complete the projects. The identified projects are titled "Chicago Rivers," "Thirsty City," "The Great Debate," "H2O: Where Does it Go?," and "The Balancing Act." The project-based learning strategy provides students opportunities to actively explore real-world problems, work collaboratively, and become personally engaged with the material. The approach challenges them to think critically and gain a new appreciation of the role of geology in their own lives (Movahedzadeh et al. 2014). The projects incorporate group work (McConnell et al. 2005), role-playing and debate (Gautier and Rebich 2005), experience-based learning (Apedoe et al. 2006), and a variety of presentation modes (poster, oral, peer review) as methods to engage the students.

Collaborative learning activities influence "how students think," promoting development of higher-order thinking skills and improvement of reasoning among nonmajor students in introductory geoscience classes (McConnell et al. 2005). "Overwhelmingly favorable" changes to student performance on learning outcomes were reported by Apedoe et al. (2006) for a geoscience course utilizing inquiry-based pedagogy, but they also acknowledged initial challenges for students in adjusting to their more active role, compared to a teacher-centered classroom. The Muddy Waters course utilizes discovery, balanced with guidance and instructor support particularly at the start of the term, to familiarize students with this role. Gautier and Rebich (2005) demonstrated improved student learning outcomes with respect to complex systems, such as the urban Chicago hydrologic system that is the focus of the Muddy Waters course, through a learner-centered environment that includes role-playing and group work. Their assessment of a "Mock Environmental Summit" showed enhanced student learning of content and critical skills and improved presentation skills, while fostering civic engagement with an issue: all of these are goals built into the project constructs of the Muddy Waters course.

Chicago Rivers

NEIU is located in the Albany Park neighborhood of Chicago, prone to flooding by the North Branch of the Chicago River. One-hundred year flooding events in 2008 and 2013 resulted in closure of NEIU's campus and surrounding streets. Students visit the river and measure stream velocity and discharge. One exciting aspect for the students is the opportunity to directly wade into the river to take measurements. Students visit a nearby stream gage operated by the U.S. Geological Survey and later collect data from that gage and others in the region.

Through these activities, students are exposed to methods and equipment directly related to phenomena that impact the community. They become aware that streamflow monitoring and flood-prevention strategies are occurring right under their noses. As a final product, students collect online data on streamflow, create

FIGURE 1. Student measuring stream discharge in the North Branch of the Chicago River .

flood-frequency curves, calculate probabilities and discharges for flows of different recurrence intervals, and examine Flood Insurance Rate Maps for a specific area. Students present a poster that includes their results along with recommendations for reducing or minimizing flood damage.

Thirsty City

In this project, student teams investigate Chicago's municipal water system from drinking water source to wastewater discharge. Many students confuse the role of Lake Michigan (the regional source of drinking water) and roles of the local river/canal system (removal of treated wastewater). Questions posed address where our drinking water comes from and how it is treated to make it potable, what happens to wastewater/sewage and how it is treated before if it is discharged to local waterways, and where the treated wastewater goes after it leaves the Chicago area. Field sites include Lake Michigan beaches and the discharge point of treated wastewater into a canal. Students collect samples for analysis and make field measurements of pH, dissolved oxygen, total dissolved solids, and temperature from both field sites. They learn basic laboratory methods and colorimetric techniques to measure sulfate, chloride, nitrate, phosphate, and fluoride in their samples and then analyze tap water to see if drinking water treatment affects these parameters. Students compare their results to maximum contaminant levels (MCLs) set by the U.S. Environmental Protection Agency. As a final product, teams present posters displaying results of their measurements along with research on a specific aspect of the water treatment process (e.g. fluoridation, primary wastewater treatment, secondary treatment) assigned to each team. The resulting poster session is structured so that visitors begin by viewing posters describing the drinking water source and end with wastewater treatment and discharge, simulating the flow through the municipal water system.

The Great Debate

Current local issues are used to engage students in scientific exploration and inquiry related to a real-life matter of contention. Examples of recent topics have included, "Should the City of Chicago disinfect treated wastewater?" and "Should flow of the Chicago River be restored to its natural direction, towards Lake Michigan?" This project is often jump-started by current news stories or opinion articles. The class is divided into teams representing different perspectives on the question. Each team is assigned the role of a type of organization chosen deliberately to represent the competing and various interests represented in modern day environmental issues: governments concerned about revenue and costs (e.g. City of Chicago), advocacy groups focusing on sustainability and protection of natural resources (e.g. Friends of the Chicago River), regulatory agencies (e.g. U.S. Environmental Protection Agency), municipalities impacted by the issue (e.g. downstream locations), or those organizations directly involved (e.g. Metropolitan Water Reclamation District). Using previously gained knowledge, students investigate each side of the issue and collect data to formulate and support their arguments. Questions outlining the topics are provided to launch the research. For example, in the debate over disinfection, students were given these prompts:

1. Draw a flow chart illustrating how water from Lake Michigan may end up in the Mississippi River and the Gulf of Mexico.

2. Describe eutrophication, and explain its relationship to discharge of wastewater and the Gulf of Mexico Dead Zone.
3. Illustrate the basic steps in sewage treatment.

The project culminates in a formal, structured, in-class debate that is evaluated with a rubric for the factual content of arguments, logical presentation, and communication skills.

H2O: Where Does It Go?

This project addresses water usage and water management on the NEIU campus. Groups of students play the role of environmental consulting firms, hired by the campus Facilities Management office to assess tap water usage, wastewater generation and management, and stormwater management. Students are tasked with creating a professional-looking consulting report with suggestions on how to do the following:

1. Minimize the quantity of tap water used on campus.
2. Minimize the quantity of water exiting campus through sanitary sewers.
3. Minimize the quantity of water leaving campus through stormwater runoff.

To introduce the project, students are led on a field trip throughout the campus and asked to identify how water, specifically stormwater runoff, moves through different areas of campus (parking lots, grassy areas, storm sewers, detention basin). Students are introduced to concepts of infiltration and surface runoff through a discussion of the hydrologic cycle within their urban environment, emphasizing both natural and anthropogenic aspects. Another campus field trip identifies locations of underground water vaults at points where the city tap water enters the campus and initiatives designed to better manage stormwater, such as sections of permeable pavement and native vegetation plantings. Involving the campus Chief Engineer, who participates in the field trips and provides a new perspective on the nuts and bolts of the institutional efforts to manage water, especially engages students with this real-life issue on their campus.

As part of their consulting report, students must provide data on quantities of tap water used by NEIU, water precipitating on campus, and water leaving campus through storm sewers each year. Students collect annual precipitation data from the NOAA website and calculate campus area using maps. They then calculate total volume of precipitation, requiring unit conversions and understanding the difference between linear, areal, and volume measurements. The final report includes data on water usage and management as well as descriptions of how tap water is used, where sanitary sewage is produced, and what happens to precipitation that falls on campus, along with the students' recommendations on minimizing tap water usage, minimizing wastewater production, and minimizing the stormwater leaving campus. Given the level of mathematics required for this project and the level of math proficiency of incoming students, this is a very challenging project. Our goal is that students see how mathematics and science are utilized on their own campus, for an issue in which they have a personal stake.

The Balancing Act

In the final project of the course, students calculate annual water budgets for local watersheds. Building on concepts learned in "H2O: Where Does It Go?" and "Chicago Rivers," this project challenges students with calculations of area and volume, unit conversions, and gathering and analyzing actual data. Students are assigned a watershed, a NOAA precipitation gage, and a USGS stream gage from which to gather online data. They calculate the total amount of water entering the watershed as precipitation and the total amount of water leaving the watershed as streamflow. They also are provided with total population and per capita water usage for their assigned watershed, with some notes on the sources of municipal water for the basin (for example, inter-basin transfer or ground water wells). A worksheet is provided to guide students as they organize and calculate inflows and outflows, and they are asked to fill in blanks with their calculated results for each component of the water budget. Students are prompted to calculate the yearly amount of evapotranspiration, which is not available online but must be estimated using inflow and outflow data; the value for evapotranspiration is used to balance the water budget.

TABLE 2. Continuation and Graduation Rates of First-Time Freshman at NEIU who took ESCI 109W, a Different FYE Course, and No FYE Course At All

				Continuation and Graduation Rates								
Cohort Entry Term	FYE Enrollment Status	Head Count	Average ACT	% STEM Major	% Continued to Spring of Year 1	% Continued to Year 2	% Continued to Year 3	% Continued to Year 4	% Graduated by Year 4	% Continued to Year 5	% Graduated by Year 5	% Continued to Year 6
Fall 2010	Enrolled in ESCI-109W	26	19.7	19%	81%	58%	39%	35%	8%	35%	23%	15%
	Enrolled in other FYE courses	767	18.9	11%	89%	68%	49%	43%	4%	37%	15%	23%
	Not enrolled in any FYE courses	248	18.9	4%	62%	45%	29%	26%	2%	20%	8%	15%
	Total	1041	18.9	9%	82%	62%	44%	39%	4%	33%	14%	21%
Fall 2011	Enrolled in ESCI-109W	58	18.3	24%	98%	81%	60%	50%	3%	36%	3%	
	Enrolled in other FYE courses	665	19.0	11%	88%	64%	50%	43%	4%	37%	4%	
	Not enrolled in any FYE courses	226	19.4	7%	60%	46%	34%	27%	3%	21%	3%	
	Total	949	19.0	11%	82%	61%	47%	40%	4%	33%	4%	
Fall 2012	Enrolled in ESCI-109W	33	18.3	27%	88%	49%	42%	33%				
	Enrolled in other FYE courses	715	18.7	10%	87%	68%	50%	43%				
	Not enrolled in any FYE courses	291	18.4	6%	53%	40%	30%	24%				
	Total	1039	18.6	9%	78%	60%	44%	37%				
Fall 2013	Enrolled in ESCI-109W	24	19.8	8%	88%	58%	46%					
	Enrolled in other FYE courses	645	18.7	11%	85%	62%	46%					
	Not enrolled in any FYE courses	139	19.4	6%	50%	44%	33%					
	Total	808	18.8	10%	80%	59%	44%					
Fall 2014	Enrolled in ESCI-109W	13	21.1	0%	85%	62%						
	Enrolled in other FYE courses	620	18.8	9%	83%	62%						
	Not enrolled in any FYE courses	137	18.1	5%	68%	47%						
	Total	770	18.8	8%	80%	59%						
Fall 2015	Enrolled in ESCI-109W	23	18.4	4%	74%							
	Enrolled in other FYE courses	516	18.4	2%	83%							
	Not enrolled in any FYE courses	210	17.9	3%	75%							
	Total	749	18.3	3%	80%							

Notes: 1) FYE course enrollment status was based on any FYE enrollment during the first year in college.
2) Percent of students with a declared major in STEM is based on the latest major on record as of March 2016.

Conclusion

Using a SENCER approach that considers a variety of community-related issues, we created a course that teaches fundamental scientific concepts, develops critical thinking and analytical reasoning skills, connects students to their community, and increases students' awareness of the geologic world around them, specifically in the urban environment of Chicago. Development and implementation were initially funded by a grant from the National Science Foundation (Award # 0914497), and the course has been successfully institutionalized. It has been taught ten times between 2010 and 2015, to a total of 159 students, and continues to be a popular course within our curriculum.

Initial analysis of data on the retention of students who have taken the course (compared to students who took a different FYE course and those who took none at all) is presented in Table 2. Also shown are the percentages of students in these groups who have declared a major in a STEM field, and graduation rates. With the smaller pool of students who have taken Muddy Waters, we expect to see the variation shown in the data. We also have considered the relative difficulty of a natural science laboratory course for first-year students compared to other non-STEM FYE courses. Further analysis of these data, including a separate accounting for retention of STEM majors, a comparison of the courses taken by Muddy Waters students following this course with those taken by other students, and demographic analysis is warranted to further explore the trends and variation seen here.

Given the nature of the course, there are particular challenges that we encountered in its design, implementation, and delivery. Some of these challenges are those that are common to many First-Year Experience courses (e.g. delivering content-related material at an appropriate level, incorporation of student success skills training). Challenges specific to this laboratory course in the natural sciences include

1. Generating and capturing student interest by making the projects personally relevant to a diverse body of students.
2. Engaging students who have a wide range of mathematical, reading, and writing preparation and skills.
3. Given the large amount of group work and cooperative learning, assembling groups with positive dynamics that represent the wide variety of preparation mentioned above and providing all of the students with the opportunity to learn from each other.
4. Determining the scaffolding of mathematical skills appropriate for the projects in order to support student success.
5. Overcoming the initial hesitation on the part of the students to some of the field activities. (This hesitation quickly abated after the first field sessions for the most part.)
6. Handling the logistics involved with transportation and access to field sites.

Moving forward, we continue to modify the course to keep the topics current and, what is even more important, personally relevant to the students. Along with this we will continue to develop the skill sets needed by the students to successfully complete the course. We continue to seek innovative and novel ways to increase the relevance of geoscience and STEM-related professions and academic tracks. Another outcome of the course was the expressed desire of our Earth Science majors to have us offer them a similar course at a major level, especially once they observed the field and laboratory activities that were central to the course. We plan to develop such a major-level course in the future. We have successfully used Muddy Waters as a recruitment pool for research opportunities geared for early-career undergraduate students (USDA-NIFA Hispanic-Serving Institutions Grant Program Award # 2010-02071) and are currently preparing a manuscript on these results. Overall, we will continue to focus on methods and approaches to increase the participation of underrepresented groups in the STEM disciplines, and more specifically in the geosciences.

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